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Colyer

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[54] **HIGH-AVAILABILITY WWW COMPUTER SERVER SYSTEM WITH PULL-BASED LOAD BALANCING USING A MESSAGING AND QUEUING UNIT IN FRONT OF BACK-END SERVERS**

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[73] Assignee: **International Business Machines Corp.**, Armonk, N.Y.

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[22] Filed: **Jul. 23, 1997**

[30] **Foreign Application Priority Data**

Dec. 7, 1996 [GB] United Kingdom 9625454

[51] **Int. Cl.**[7] **G06F 13/00**

[52] **U.S. Cl.** **709/201**; 709/203; 709/235

[58] **Field of Search** 395/200.33, 200.65, 395/200.56, 200.32; 709/201, 203, 235

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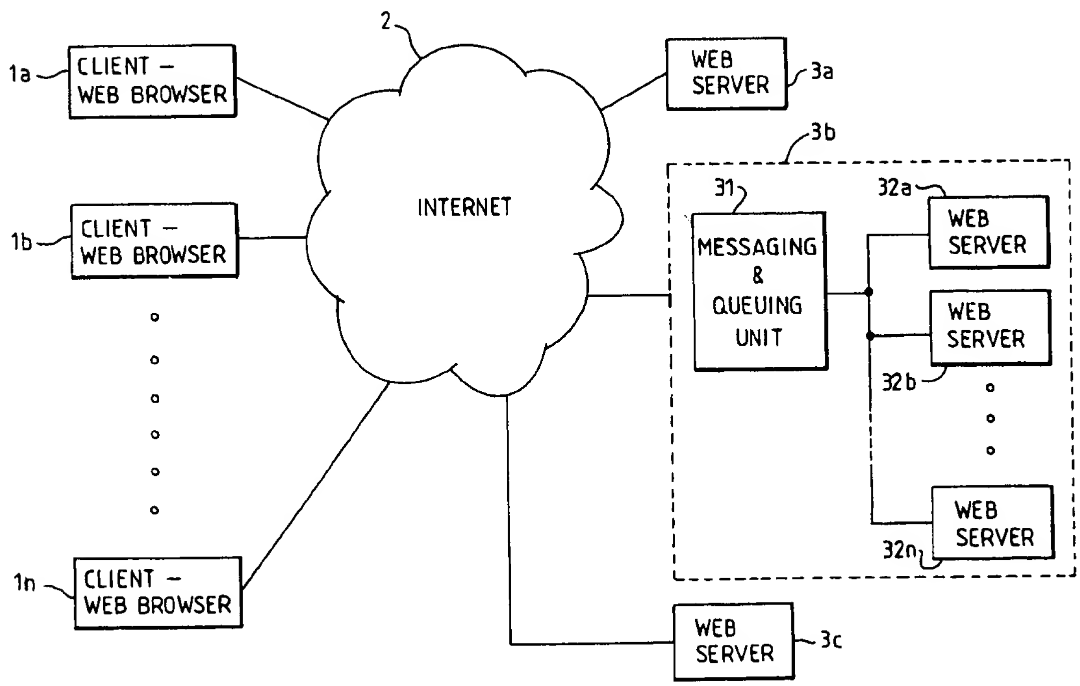
Primary Examiner—Krisna Lim
Attorney, Agent, or Firm—A. Bruce Clay

[57] **ABSTRACT**

A high-availability computer server system, and method of operation thereof, capable of serving a large number of requests received from a plurality of computer client devices connected through a network to said server system, said requests specifically identifying said server system, said server system comprising: a messaging and queuing unit having an input connected to said network upon which said requests identifying said server system are received, and an output; and a plurality of server units connected in parallel to said output of said messaging and queuing unit, where each server unit pulls requests off of a queue in the messaging and queuing unit.

6 Claims, 2 Drawing Sheets



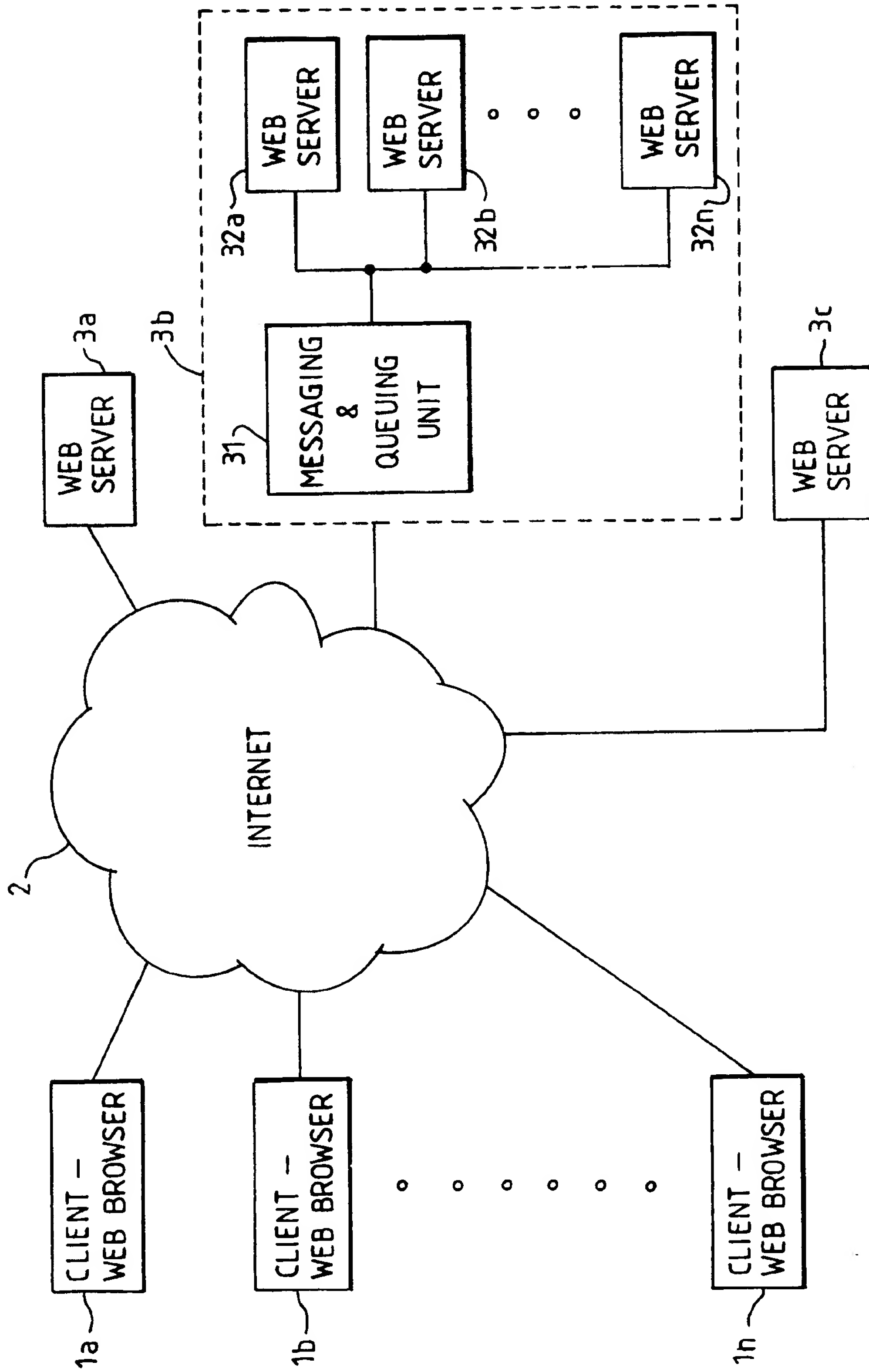

WEB SERVER
32a
WEB SERVER
32b
WEB SERVER
32n
3a
3b
MESSAGING & QUEUING UNIT
31
3c
WEB SERVER
WEB SERVER
INTERNET
2
CLIENT – WEB BROWSER
1a
CLIENT – WEB BROWSER
1b
CLIENT – WEB BROWSER
1n

FIG. 1

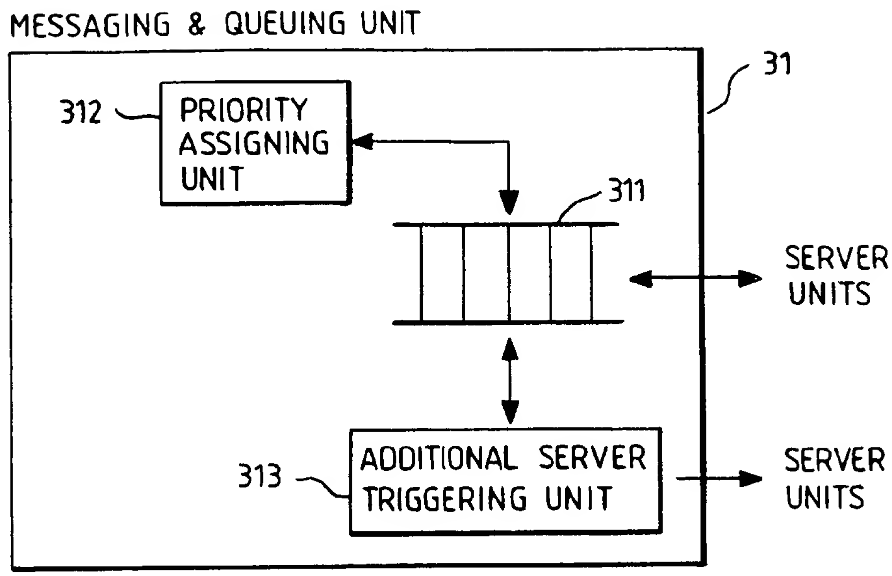


FIG. 2 PRIOR ART

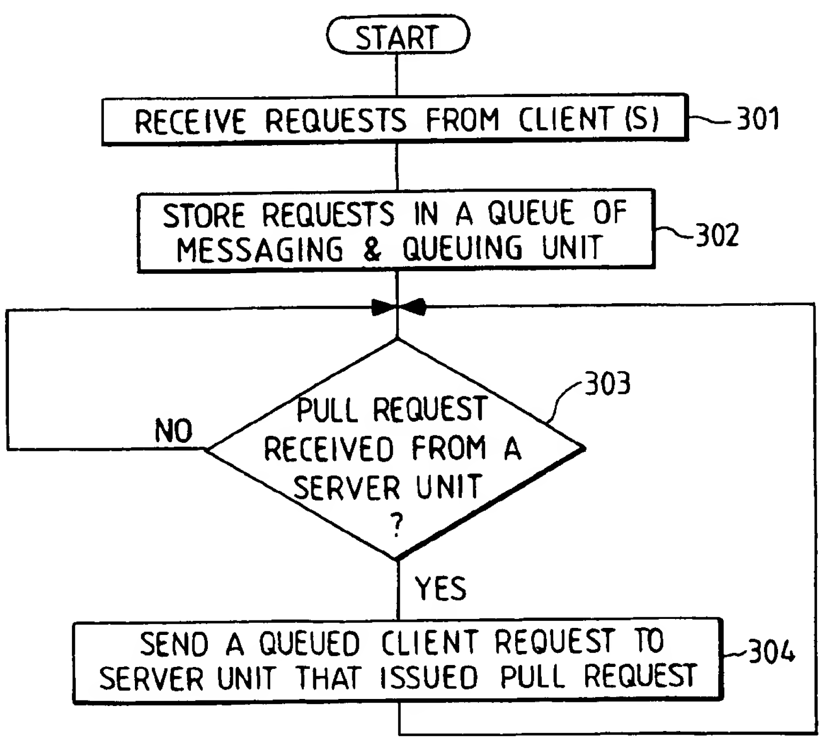


FIG. 3

HIGH-AVAILABILITY WWW COMPUTER SERVER SYSTEM WITH PULL-BASED LOAD BALANCING USING A MESSAGING AND QUEUING UNIT IN FRONT OF BACK-END SERVERS

FIELD OF THE INVENTION

This invention is in the computer networking field. It specifically is in the field of high-availability server computer devices capable of providing the same information to a large number of client computer devices.

BACKGROUND OF THE INVENTION

Just as computers have become more and more prevalent in everyday life, networks of linked computers have become important in distributing information amongst computer users. Through such networks, computer users can share information creating a virtual publishing medium which has become a viable alternative for the print medium.

A 'network' of computers-can be any number of computers that are able to exchange information with one another. The computers may be arranged in any configuration and may be located in the same room or in different countries, so long as there is some way to connect them together (for example, by telephone lines or other communication systems) so they can exchange information. Just as computers may be connected together to make up a network, networks may also be connected together through tools known as bridges and gateways. These tools allow a computer in one network to exchange information with a computer in another network. The Internet is a network of networks having no single owner or controller and including large and small, public and private networks, and in which any connected computer running Internet Protocol software is, subject to security controls, capable of exchanging information with any other computer which is also connected to the Internet. This composite collection of networks which have agreed to connect to one another relies on no single transmission medium (for example, bidirectional communication can occur via satellite links, fibreoptic trunk lines, telephone lines, cable TV wires and local radio links).

The World Wide Web (WWW) Internet service is a wide area information retrieval facility which provides access to an enormous quantity of network-accessible information and which can provide low cost communications between Internet-connected computers. Information about the World Wide Web can be found in "Spinning the Web" by Andrew Ford (International Thomson Publishing, London 1995) and "The World Wide Web Unleashed" by John December and Neil Randall (SAMS Publishing, Indianapolis 1994). Use of the WWW is growing at an explosive rate because of its combination of flexibility, portability and ease-of-use, coupled with interactive multimedia presentation capabilities. The WWW allows any computer connected to the Internet and having the appropriate software and hardware configuration to retrieve any document that has been made available anywhere on the Internet. The retrievable documents on the WWW include 'HyperMedia' documents—i.e. documents which may be text documents or other forms of media such as sounds and images and which have links ('Ihyperlinks') to other documents. The format of text documents on the WWW is a standard format in HTML (HyperText Markup Language), such that a document created on one operating system and hardware platform can be read by a user on any other platform that has a Web Browser (see below). Images may be stored in separate graphics files, for example in standard GIF or JPEG format, and referenced in the HTML text such that the user is prompted to retrieve the specified image files as well as the HTML text.

Users access this information using a 'Web Browser', or 'Web client', which is software installed on the user's computer and having facilities for serving or retrieving documents from a Web Server via the Internet. Currently available Web Browsers include WebExplorer from IBM Corporation and Mosaic from NCSA. Both "WebExplorer" and "Mosaic" are trademarks of the respective companies. Such Browsers include directories and search tools and understand HTML and other WWW standard formats and can display or output files correctly in these formats. The user interface of these Web Browsers is a graphical 'point-and-click' interface (i.e. items can be selected by moving a cursor across a graphical display and then pressing a mouse button). The WWW is structured as pages or files which each have a particular Universal Resource Locator (or URL). The URL denotes both the server machine and the particular file or page on that machine. The user can either specify a particular URL or jump from one URL to an associated URL by means of the 'hyperlinks'-that is, a word or symbol on a page can be associated with another URL which is selectable, for example by clicking a mouse at the relevant location, to cause the Browser to retrieve and display the relevant page. There may be many pages resident on a single server, and associated hyperlinked pages may be located on different servers. If a URL begins "http:" then this indicates that the file contains hyperlinks. "http:" stands for "hypertext transport protocol" and is the basic communication protocol by which messages are sent over the World Wide Web and "hyperlinked" together.

When a user selects a URL for a page on a Web server system using his Web Browser, a one-shot request is sent to the relevant server which performs an action specific to that page. In many cases the server responds to the request by retrieving the requested page from a database of stored pages and transmitting the HTML page back over the Internet to the WWW client for display to the user. This is performed within the scope of a single end-to-end synchronous communication session. That is, the Browser sends its request and then waits for a response before proceeding with any further processing or initiating other requests. The Browser is said to be 'blocked' or 'suspended' while it waits for the requested response. In some cases the Browser's request will lead to the server launching an application to generate the HTML, but again the one-shot request from the Browser requires a response within the scope of the present synchronous communication session since the Browser does not provide for concurrent communication sessions and no application state information is maintained between requests. A failure to access a page requested by a Browser can be signalled back to the user by means of an error message displayed on the user's terminal, but if the server is merely slow to respond then the Browser remains suspended for an indefinite period. In practice, a user may abandon the communication attempt if the delay is unacceptable to them. There is no facility within Web Browsers for automatic retry of a request.

Modern enterprises require facilities for communication with other departments within the enterprise and with associated enterprises such as customers or suppliers, who may be in a different country. The WWW Internet service can provide a partial answer to such a requirement, providing a cost effective communication medium for inter-company communications, but the WWW Internet service's one-shot request-response communication model and the lack of

provision for parallel requests from a Browser can represent severe limitations if requested information is not available within an acceptable time period. It is often unacceptable for a sender system to be suspended indefinitely and it is unacceptable for the success of business-critical applications to be dependent on whether a server application responds to a request in time. The WWW Internet service does not provide facilities for assured delivery of messages which is a requirement of many business critical applications (that is, the application needs to know that a message it has sent will not be lost on its way to the target destination, and that it will only be sent once). Also, business applications may involve a conversation taking up many request-response pairs and the lack of any context information being carried over between Web Browser requests means that there is no facility for relating together requests which are part of the same business application.

Oftentimes, it is desirable to provide a single WWW server which can almost simultaneously provide the same information to a large number of WWW browsers. For example, IBM has recently provided networking facilities for the Olympic Games in Atlanta, Ga. in the USA. As part of this effort, a high-availability server was required, as many people all over the world were simultaneously trying to obtain access to the Web server to obtain information such as results of each Olympic competition. Each Web browser, from places all over the world, issued a request listing the URL of the IBM Olympic Web server. The server had to be capable of supplying a very large demand in terms of Web browser requests.

In these instances, one possible high availability server architecture is known (see Japanese Patent No. 2505116 owned by IBM) in which a load balancer is placed before a plurality of server computing devices. Each server computing device is capable of supplying the same information as the other server computing devices of the plurality. Many server devices are used in this way in order to provide the capability of serving a large amount of client browser requests. The load balancer periodically checks the status of each server device to determine how busy that server device is, and updates a data record appropriately. The load balancer then makes decisions as to which server device should serve the next incoming browser request based on the status of each server device as recorded in the data record. Each browser sends a generic request to "the server" specified in the URL and does not know how "the server" is handling the request. The large number of browsers simply are provided with the requested information in a fast and efficient manner.

However, these types of known high-availability servers suffer from drawbacks in that the load balancer only checks the status of each server device on a periodic basis, so oftentimes even though a particular server has been determined to be not busy at one instance of time when the load balancer checks, it may be very busy at a later time in between status checks. In such instances a particular server device can be assigned too much work and thus the respective browsers would have to wait for a long time before receiving the requested information.

Also, with the above known architecture browser requests are taken one at a time by the load balancer and assigned to server devices in the order in which they were received. However, this is disadvantageous because a browser requesting only text would have to wait for a long time while previously received graphics requests are being served (graphics requests involve much more data to be transferred than text because graphics contain much more information than text). Also, if it were particularly more important for one browser user to gain access before the others, there is no mechanism which provided for this in the prior architecture. Each request had to wait its turn.

Also, if there is a particular period of extremely high demand where all available server devices are extremely busy, the browsers are made to wait a long time before having their requests served.

The performance of this architecture is further impaired since each received browser request must be served and a reply sent back to the browser before an initial connection can be made with respect to another browser request.

The present invention has been developed with these limitations in the prior architecture in mind.

SUMMARY OF THE INVENTION

According to one aspect, the present invention provides a high-availability computer server system capable of serving a large number of requests received from a plurality of computer client devices connected through a network to said server system, said requests specifically identifying said server system, said server system comprising: a messaging and queuing unit having an input connected to said network upon which said requests identifying said server system are received, and an output; and a plurality of server units connected in parallel to said output of said messaging and queuing unit.

By using a messaging and queuing unit, the present invention prevents servers which receive requests from the unit from being overloaded, because the servers "pull" requests off of the queue (in the unit) as opposed to a load balancer "pushing" requests onto the servers without the servers asking for such requests. The server system and thus the overall client/server system thus work much more efficiently to serve client requests, especially in high volume situations where a server system receives a large amount of requests nearly simultaneously.

According to another aspect, the invention provides a method of serving requests received from a plurality of client computer devices via a computer network, each of said requests specifically identifying a specific server system, said method comprising steps of: storing, at said specific server system, said received requests into a messaging and queuing unit; and sending requests from said messaging and queuing unit to a plurality of parallel-connected server units.

According to another aspect, the present invention provides a client/server computer system having a high availability computer server system capable of serving a large number of requests received from a plurality of computer client devices connected through a network to said server system, said requests specifically identifying said server system, said server system comprising: a messaging and queuing unit having an input connected to said network upon which said requests identifying said server system are received, and an output; and a plurality of server units connected in parallel to said output of said messaging and queuing unit.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram showing a network system architecture including a server system according to a preferred embodiment of the present invention;

FIG. 2 is a block diagram showing some well-known functional units of a messaging and queuing unit, which are used in the preferred embodiment of the present invention; and

FIG. **3** is a flowchart showing methods steps carried out by a server according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. **1**, the system architecture to which a preferred embodiment of the present invention pertains includes a plurality of client Web browsers **1***a* through **1***n* connected to the Internet **2**. A plurality of Web servers **3***a*, **3***b* and **3***c* are also connected to the Internet **2**. Each client Web browser **1***a*–**1***n* can access information stored on a Web server **3***a*–**3***c* by sending a request specifically identifying the requested Web server over the Internet **2**, as described above.

Web server **3***b* is shown in further detail in FIG. **1**, as this server illustrates a server architecture according to a preferred embodiment of the present invention. Server **3***b* is a high availability server capable of serving many more requests than the other two normal availability servers **3***a* and **3***c*. Server **3***b*, for example, is providing sports scores for a popular international sporting event and is thus being accessed by browsers all over the world at almost the same time. Server **3***b* must thus be able to deal with this large volume of near simultaneous requests.

As shown, server **3***b* is broken up into a messaging and queuing unit **31** and a plurality of normal availability web servers **32***a*–**32***n*. Web servers **32***a*–**32***n* can be, for example, identical to the other servers **3***a* and **3***c*. Messaging and queuing unit **31** is a software product which can be running on one of the servers **32***a*–**32***n* or on a separate server machine included within server architecture **3***b*. The details of the messaging and queuing software unit **31** are well known in the art, however, a brief background description of such a unit will now be given to explain its function with respect to the disclosed embodiment of the present invention.

An alternative communication model to the synchronous, time-dependent 'request and await response' model (as usually used in the WWW environment) is asynchronous messaging known in the art as "messaging and queuing". A program which sends a message to a receiver program need not be blocked to await a reply from the receiver and so can continue executing, and the sender and receiver are not synchronised (serialised) with one another. Asynchronous inter-program messaging typically uses message queues as intermediate storage facilities into which messages are placed when sent from a first program and from which they can be retrieved by a receiver program when it is ready. There is no dedicated logical connection between the programs. After placing a message in a queue, the sender program can proceed to execute other tasks which may involve sending messages to other programs in the network. It is known in the art to provide asynchronous messaging systems which support inter-program communication across heterogeneous networks, and which shield application programs (which are each written for a particular operating system environment) from the complexities of the network and from the work of maintaining and locating message queues. Such messaging systems are important to many commercial enterprises who need to achieve effective interoperation between their various business application programs but whose data processing resources comprise a range of disparate operating system and hardware environments.

Message queuing and commercially available message queuing products are described in "Messaging and Queuing Using the MQI", B. Blakeley, H. Harris & R. Lewis, McGraw-Hill, 1994, and in the following publications which are available from IBM Corporation: "An Introduction to Messaging and Queuing" (IBM Document number GC33-0805-00) and "MQSeries-Message Queue Interface Technical Reference" (IBM Document number SC33-0850-01). IBM and MQSeries are trademarks of IBM Corporation. IBM's MQSeries messaging software products provide transactional messaging support, synchronising messages within logical units of work in accordance with a messaging protocol which gives assured once and once-only message delivery even in the event of system or communications failures. MQSeries products provide assured delivery by not finally deleting a message from storage on a sender system until it is confirmed as safely stored by a receiver system, and by use of sophisticated recovery facilities. Prior to commitment of transfer of the message upon confirmation of successful storage, both the deletion of the message from storage at the sender system and insertion into storage at the receiver system are kept 'in doubt' and can be backed out atomically in the event of a failure. This message transmission protocol and the associated transactional concepts and recovery facilities are described in international patent application WO 95/10805 and U.S. Pat. No. 5465328, which are incorporated herein by reference.

As requests (messages) having URL's specifying server **3***b* are received (step **301** of FIG. **3**) from client web browsers **1***a*–**1***n* over the Internet, messaging and queuing unit **31** of server **3***b* receives and stores (step **302**) the requests in a queue. The web servers **32***a*–**32***n* inform (step **303**) the messaging and queuing unit **31** when they are ready to receive a request from the queue. That is, when server **32***a* has finished serving previous requests and is now sitting idly, it sends a message to the messaging and queuing unit **31** asking for another request to serve. The same applies for the other servers **32***b*–**32***n*. Messaging and queuing unit **31** then sends (step **304**) a queued client request to a server unit in response to having received a request from the server unit for a client request. This is known as a "pull" model since servers **32***a*–**32***n* "pull" requests off of the queue when they are ready. This has the advantage of not overloading a server since it is not given any work to do until it asks for such work. Servers **32***a*–**32***n* can thus operate much more efficiently and effectively.

A unique correlation identifier is assigned to each HTTP request as it is received by messaging and queuing unit **31**. A received request is then placed on the request queue of unit **31**. The unit **31** then waits (by suspending a blocking MQGET call) until a server **32***a*–**32***n* which indicated that it was ready to receive a request returns a reply having the assigned correlation identifier to unit **31**. The reply is stored in an HTTP reply queue in unit **31** and sent back to the browser **1***a*–**1***n* that initiated the request.

Web servers **32***a*–**32***n* are adapted so that instead of monitoring their usual port (port **80** for most servers) for HTTP requests (as the other servers **3***a* and **3***c* do) they monitor the request queue of unit **31**. Alternatively, a bridge program could be run alongside a respective server **32***a*–**32***n* to monitor the request queue of unit **31** and supply requests to port **80** of the server. In this latter configuration, the server's reply would be received by the bridge program and translated into a message to be added to the HTTP reply queue of unit **31**.

By using a messaging and queuing unit between the Internet and a plurality of parallel-connected servers, messages stored in the messaging and queuing unit **31** can be prioritized using well-known messaging and queuing tech-

niques. FIG. 2 shows a priority assigning unit **312**, which assigns priorities to client request that are stored in queue **311**, both of these elements are parts of the well-known structure of a messaging and queuing unit. For example, if one client Web browser **1***a* is requesting textual information (e.g., sports scores) and another client Web browser **1***b* is requesting graphical data (a colour picture of the sports arena), it would be useful to be able to serve the textual information first, as the graphical information takes much longer to serve as it is much more data intensive. Browser **1***a* would thus be quickly served the simple text request. Browser **1***b* would expect to wait longer for the graphics request and thus it is highly advantageous to serve the text request first. The two HTTP requests stored in the queue of unit **31** are examined by looking at the extensions of their URL's. If the extension refers to text (HTML) this HTTP request is moved ahead of a request having an extension GIF (signifying graphical image data).

Also, a well-known triggering feature (see additional server unit triggering unit **313** in FIG. **2**) of messaging and queuing unit **31** can be employed to "wake up" additional servers **32***a*–**32***n* if the queued messages surpass a threshold number. That is, there may be times of low usage where it is not desirable to have all of the servers **32***a*–**32***n* active. There are other times of high usage when more servers of the set **32***a*–**32***n* should be active. Thus, messaging and queuing unit **31** periodically checks the number of queued requests and if it is higher than a threshold amount, additional servers can be triggered to turn on during these periods of high usage.

Further, since messaging and queuing unit **31** accepts an Internet connection for each request and places the received HTTP request in a queue, it can then quickly service the next request by immediately accepting another connection. In prior architectures it was necessary to wait until a received request was served by a server and a reply sent back through the opened connection before another connection could be accepted to receive the next request from the Internet.

Accordingly, the performance and availability of Web Servers can be greatly enhanced according to the preferred embodiment of the present invention. While the preferred embodiment has been described in the context of the World Wide Web as the network, many other networks of connected computer devices are also within the scope of the invention.

We claim:

1. An Internet World Wide Web (WWW) computer server system which serves requests received from a plurality of WWW browser computer client devices connected through the Internet to said server system, said requests specifically identifying said server system, said server system comprising:

a messaging and queuing unit having an input connected to the Internet upon which said requests identifying said server system are received, and an output; and

a plurality of server units connected in parallel to said output of said messaging and queuing unit, wherein each server unit pulls requests off of a queue included in said messaging and queuing unit.

2. The system of claim **1** wherein said messaging and queuing unit includes means for assigning priority to received requests.

3. The system of claim **2** wherein said means for assigning priority assigns higher priority to text requests as compared to graphics requests.

4. The system of claim **1** wherein said messaging and queuing unit includes means for triggering an additional server unit as the number of unserved requests received by said messaging and queuing unit surpasses a threshold amount.

5. The system of claim **1** wherein said messaging and queuing unit includes means for sending a request to one of said plurality of server units in response to said server unit informing said messaging and queuing unit that said server unit is ready to serve a request.

6. A method of serving Internet World Wide Web (WWW) requests received from a plurality of WWW browser client computer devices via the Internet, each of said requests specifically identifying a specific WWW server system, said method comprising steps of:

storing, at said specific server system, said received requests into a messaging and queuing unit; and

sending requests from said messaging and queuing unit to a plurality of parallel-connected server units in response to the receipt of pull requests from the server units.

* * * * *

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United States Patent [19]

Black et al.

[11] **Patent Number: 5,878,056**

[45] **Date of Patent: Mar. 2, 1999**

[54] **MESSAGE TRANSFER IN A COMMUNICATION NETWORK**

[75] Inventors: **George Black; Peter Johnson**, both of Winchester, United Kingdom

[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[21] Appl. No.: **822,974**

[22] Filed: **Mar. 21, 1997**

[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[6] **H04L 1/14**

[52] **U.S. Cl.** **371/32**; 395/200.67; 370/249

[58] **Field of Search** 371/32, 33; 395/200.67, 395/671, 182.11; 370/245

[56] **References Cited**

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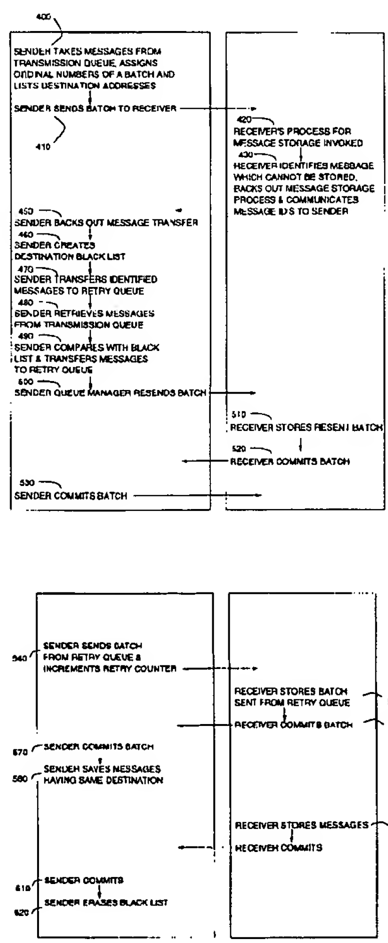
Primary Examiner—Glenn A. Auve

Attorney, Agent, or Firm—Jeanine S. Ray-Yarletts

[57] **ABSTRACT**

Provided are methods and systems for message transfer between nodes of a communication network which reduce the occurrence of repeated transfer failures associated with a particular message or messages within a batch. When a batch of messages sent from a sender node cannot be stored at a receiver node, the receiver node identifies which messages within the batch caused the rejection and communicates this information to the sender node. The sender node records the destinations of the identified messages in a "destination black list", and then separates messages having these identified problematic destinations from the other messages. The batch of messages is then retransmitted to the receiver, but with the messages which have the identified problematic destinations excluded from the batch. These excluded messages are then dealt with separately without causing repeated rejection of the batch.

14 Claims, 6 Drawing Sheets



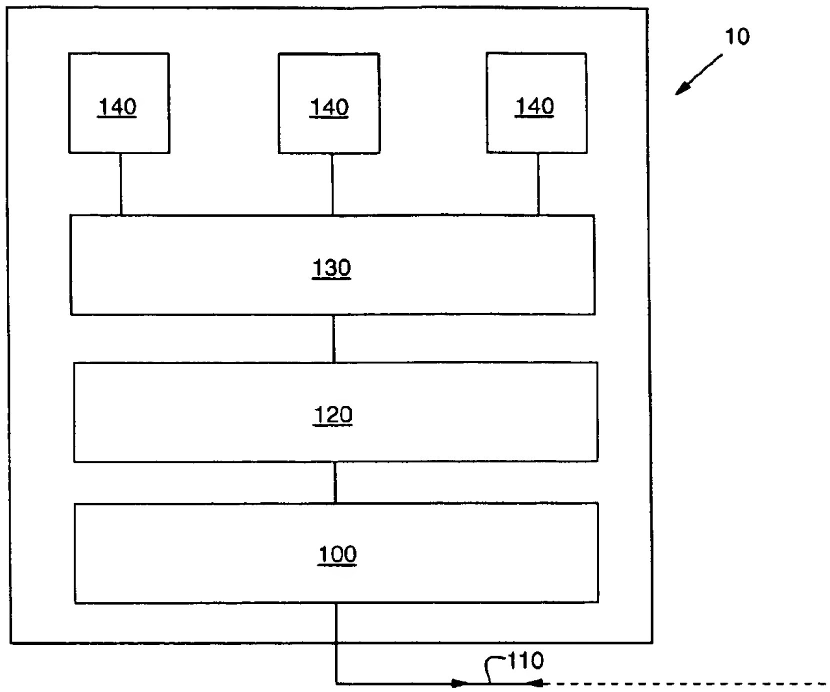


FIG. 1

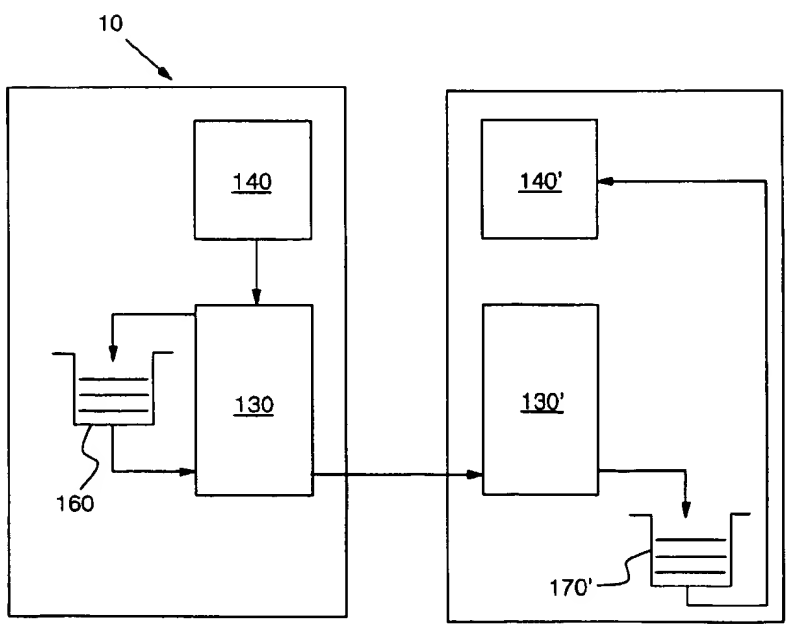


FIG. 2

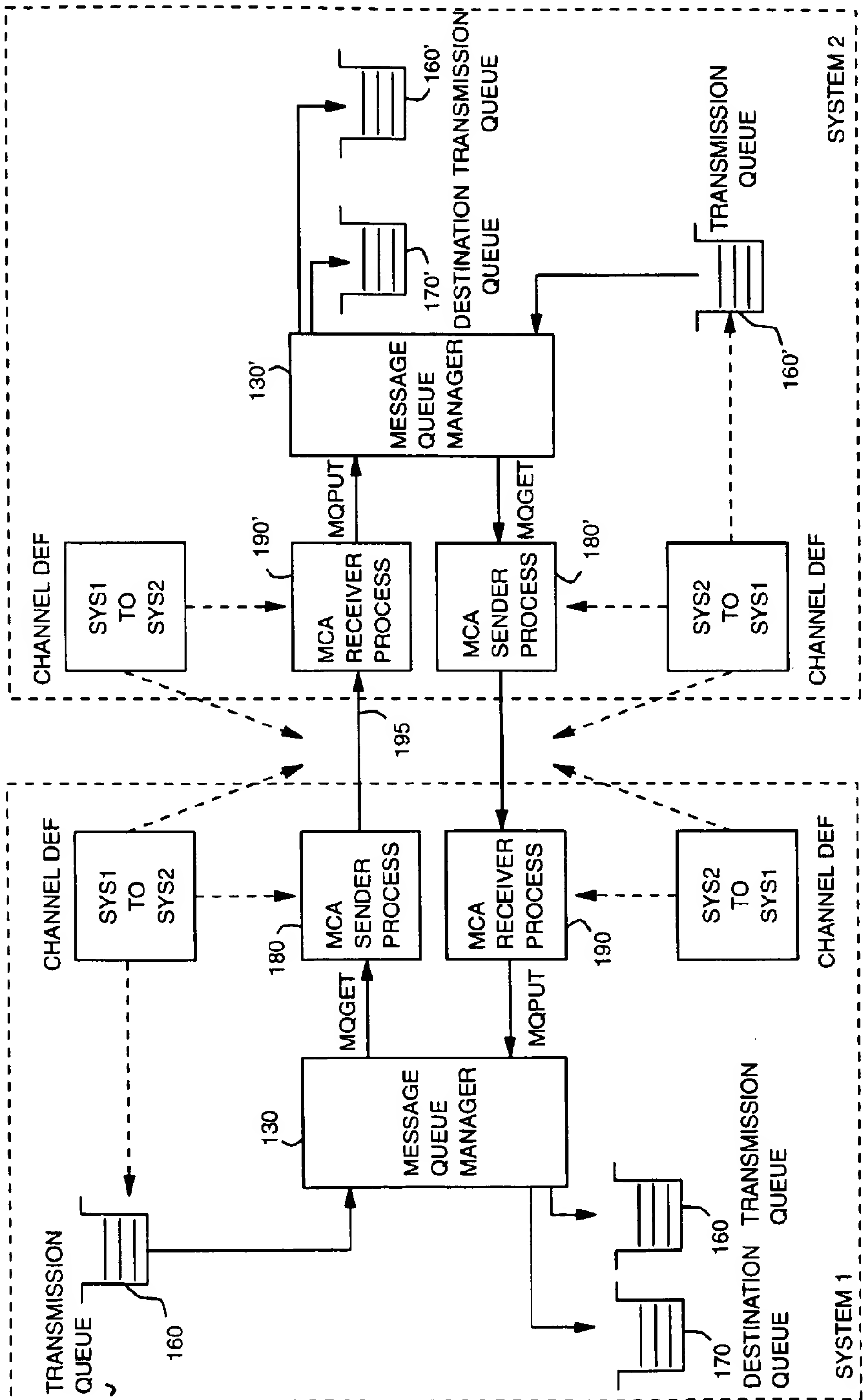

SYSTEM 2
CHANNEL DEF
SYS1 TO SYS2
MCA RECEIVER PROCESS
MCA SENDER PROCESS
SYS2 TO SYS1
CHANNEL DEF
MQPUT
MQGET
MESSAGE QUEUE MANAGER
DESTINATION QUEUE
TRANSMISSION QUEUE
TRANSMISSION QUEUE
130'
190'
180'
170'
160'
195
SYSTEM 1
CHANNEL DEF
SYS1 TO SYS2
MCA SENDER PROCESS
MCA RECEIVER PROCESS
SYS2 TO SYS1
CHANNEL DEF
MQGET
MQPUT
MESSAGE QUEUE MANAGER
TRANSMISSION QUEUE
TRANSMISSION QUEUE
DESTINATION QUEUE
130
180
190
160
170

FIG. 3

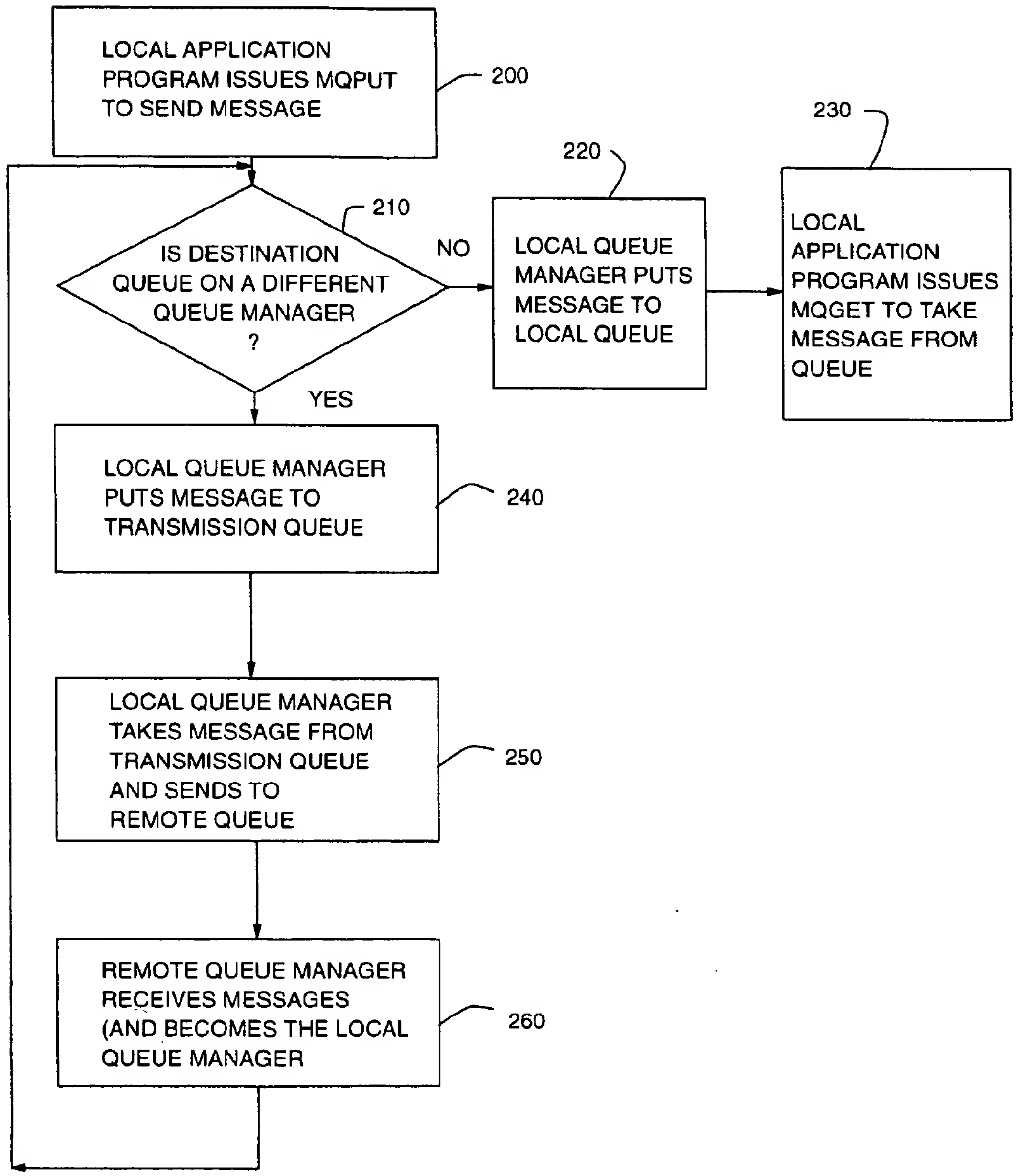

LOCAL APPLICATION PROGRAM ISSUES MQPUT TO SEND MESSAGE
200
IS DESTINATION QUEUE ON A DIFFERENT QUEUE MANAGER ?
210
NO
YES
LOCAL QUEUE MANAGER PUTS MESSAGE TO LOCAL QUEUE
220
LOCAL APPLICATION PROGRAM ISSUES MQGET TO TAKE MESSAGE FROM QUEUE
230
LOCAL QUEUE MANAGER PUTS MESSAGE TO TRANSMISSION QUEUE
240
LOCAL QUEUE MANAGER TAKES MESSAGE FROM TRANSMISSION QUEUE AND SENDS TO REMOTE QUEUE
250
REMOTE QUEUE MANAGER RECEIVES MESSAGES (AND BECOMES THE LOCAL QUEUE MANAGER
260

FIG. 4

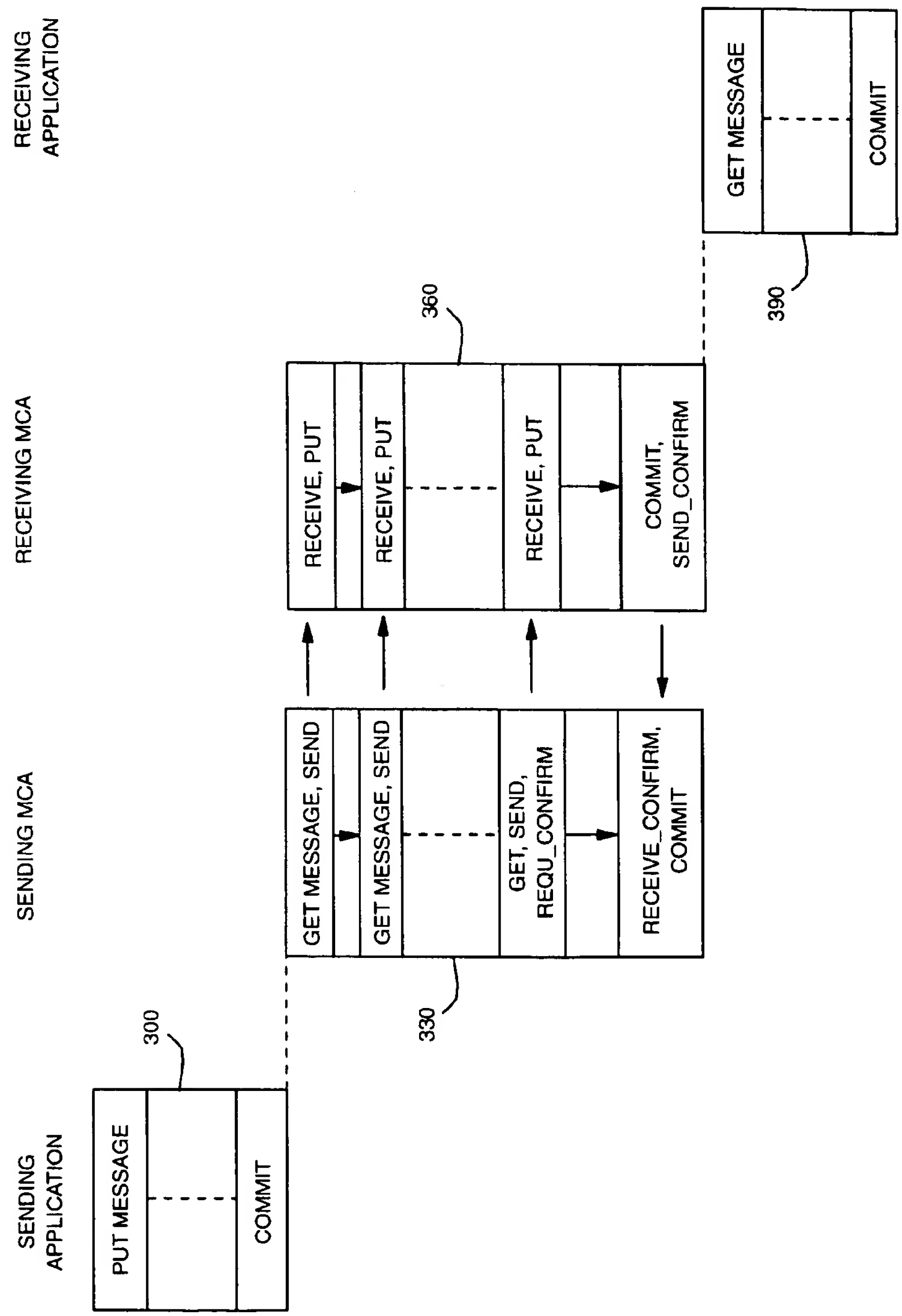

SENDING APPLICATION
SENDING MCA
RECEIVING MCA
RECEIVING APPLICATION
PUT MESSAGE
COMMIT
300
GET MESSAGE, SEND
GET MESSAGE, SEND
GET, SEND, REQU_CONFIRM
RECEIVE_CONFIRM, COMMIT
330
RECEIVE, PUT
RECEIVE, PUT
RECEIVE, PUT
COMMIT, SEND_CONFIRM
360
GET MESSAGE
COMMIT
390

FIG. 5

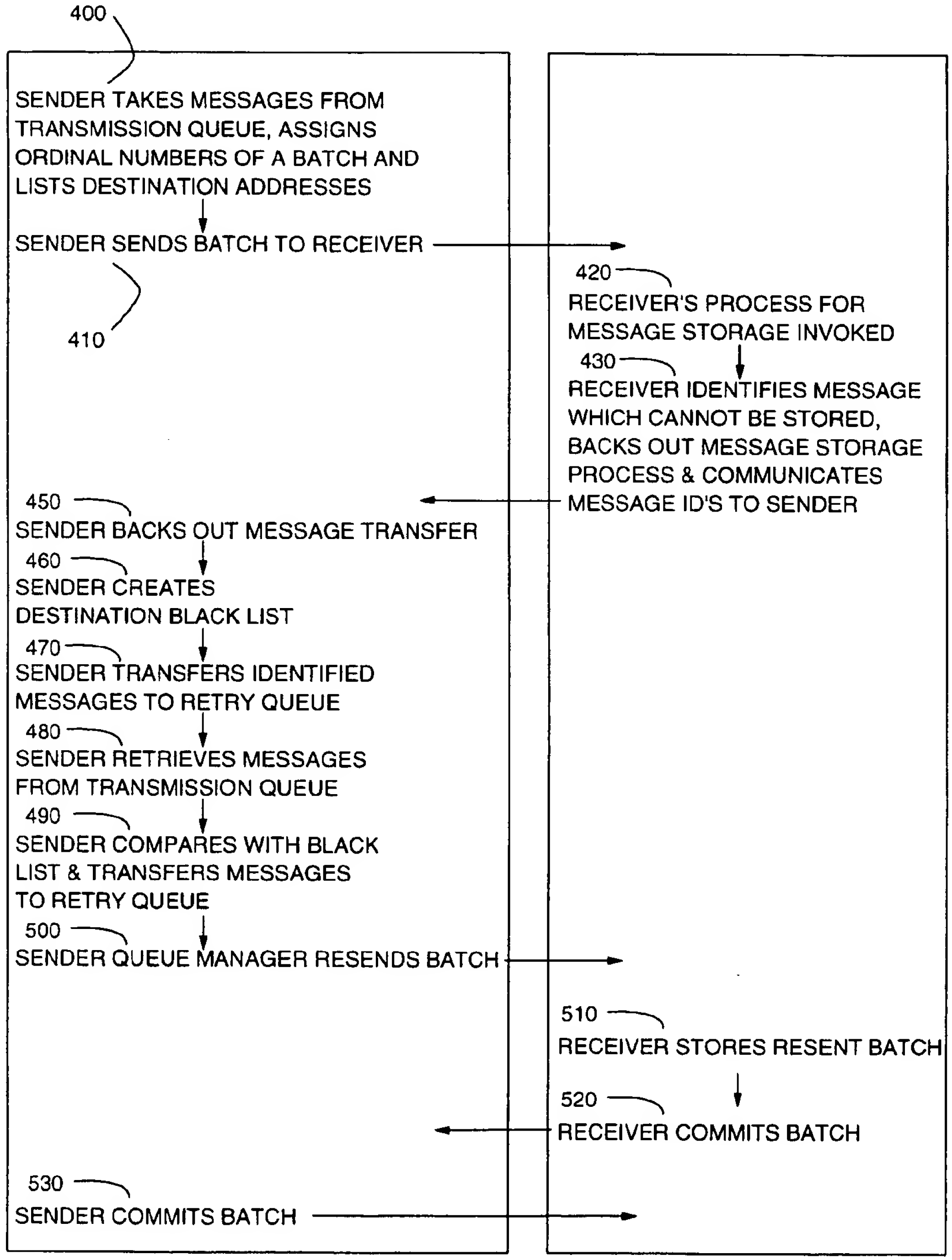
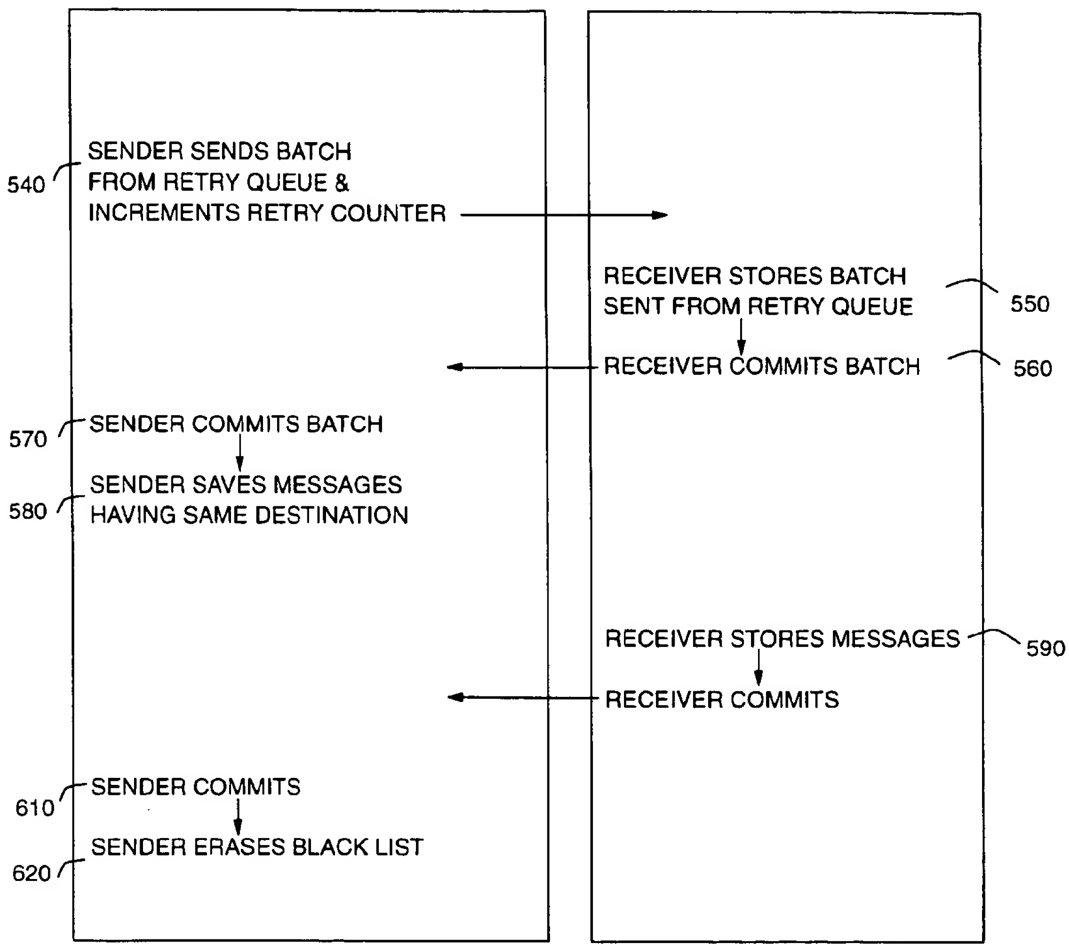

400
SENDER TAKES MESSAGES FROM TRANSMISSION QUEUE, ASSIGNS ORDINAL NUMBERS OF A BATCH AND LISTS DESTINATION ADDRESSES
SENDER SENDS BATCH TO RECEIVER
410
420
RECEIVER'S PROCESS FOR MESSAGE STORAGE INVOKED
430
RECEIVER IDENTIFIES MESSAGE WHICH CANNOT BE STORED, BACKS OUT MESSAGE STORAGE PROCESS & COMMUNICATES MESSAGE ID'S TO SENDER
450
SENDER BACKS OUT MESSAGE TRANSFER
460
SENDER CREATES DESTINATION BLACK LIST
470
SENDER TRANSFERS IDENTIFIED MESSAGES TO RETRY QUEUE
480
SENDER RETRIEVES MESSAGES FROM TRANSMISSION QUEUE
490
SENDER COMPARES WITH BLACK LIST & TRANSFERS MESSAGES TO RETRY QUEUE
500
SENDER QUEUE MANAGER RESENDS BATCH
510
RECEIVER STORES RESENT BATCH
520
RECEIVER COMMITS BATCH
530
SENDER COMMITS BATCH

FIG. 6A



540
SENDER SENDS BATCH
FROM RETRY QUEUE &
INCREMENTS RETRY COUNTER
RECEIVER STORES BATCH
SENT FROM RETRY QUEUE
550
RECEIVER COMMITS BATCH
560
570
SENDER COMMITS BATCH
580
SENDER SAVES MESSAGES
HAVING SAME DESTINATION
RECEIVER STORES MESSAGES
590
RECEIVER COMMITS
610
SENDER COMMITS
620
SENDER ERASES BLACK LIST

FIG. 6B

MESSAGE TRANSFER IN A COMMUNICATION NETWORK

FIELD OF THE INVENTION

The present invention relates to message transfer between nodes of a communications network, and to methods and systems for dealing with message transfer failures.

BACKGROUND

Processes located at nodes of a communications network frequently need to be able to send messages to and receive messages from other processes at different nodes. It is important for the efficiency of some of these data communications to be able to transfer messages in a batch of several messages. Such batching of messages speeds message throughput and can reduce network communication traffic by limiting control communications (such as sender and receiver location information, confirmations of receipt and commit processing) to one set of communication flows per batch instead of one set per message. In transaction processing systems, committing updates on completion of a transaction involves a relatively high processing overhead, so only committing at the end of a batch of transactional updates can significantly improve system efficiency.

In the context of the present invention the phrases "message transfer" and "messaging" are to be interpreted as including, where the context permits, packet switching and the transfer between network nodes of any data transfer unit, and including the transfer of any application data message, error message, reconfiguration message, or network status message. In a distributed data processing network, the network nodes are data processing resources, e.g. (i) computer systems having computer programs installed thereon, these systems being connected for communication over underlying network links, or, (ii) in networks for which communications management programs are the network entities to which messages are sent, the communication management programs. In a packet switching network, the "nodes" are the switches.

Communication between remote processes within a distributed network may involve multiple intermediate network links and nodes forming a communication path. Messages travelling from one node of the network to an adjacent node may have different ultimate destinations and yet it may be most efficient to transfer several of these messages together as a batch. The sending node can request confirmation that the batch has successfully arrived and been stored at the adjacent receiving node as a final stage of transmission of the batch, such that it is unnecessary to check successful transfer of each message separately.

There are various reasons why it may not be possible to successfully store one or more of the messages of a batch at the receiving node. For example, the destination address may not be recognized (perhaps the named destination does not exist), or there may be a problem with the message storage facilities of the receiving node. For example, the storage facility may already be full or the system may have been set so as not to allow messages to be added to storage.

It is a general requirement of data processing systems to ensure that critical data communications (e.g. messages which affect critical data, such as a funds transfer in a banking system) are successfully completed once and once only. Thus, facilities are required for recovering from failures, whether these be failures of the data processing systems, their connecting communication links, or application detected errors. In a messaging system that uses batching, the implementation of this requirement may involve ensuring that if not all of the batch of messages transmitted from a first node can be successfully stored at the next adjacent node, then the whole batch is backed out. That is, either the whole batch is successfully transferred and stored at a receiver node or no messages within the batch are stored at the receiver node and all of the messages are retained in storage at the sender node. Transfer of a backed out batch of messages can subsequently be retried.

A problem with this all-or-nothing approach to batch transfer of messages is that repeated backouts of a batch will impact message transfer performance. A large batch of messages may repeatedly fail to be transferred because of a recurring problem which is associated with only one message in the batch.

One solution to this problem which avoids repeatedly backing out the entire batch is to store problem messages on a "dead-letter queue" at the receiver node. Rather than simply discarding problem messages (which is unacceptable in systems where messages must not be lost), a dead letter queue is provided as a storage facility of the receiver system into which undeliverable messages are placed. Use of a dead letter queue makes the problem visible and enables fault correction processes to be used, or the messages to be redirected, or messages communicating the occurrence of the message delivery problems to be sent back to the origin of the message.

Clearly, some means of processing the dead-letter queue is required. Secondly, it may not be possible to store all problem messages on a dead-letter queue. There may be no dead-letter queue defined, or if defined it may be full or there may be access problems. In such cases, it is again necessary to reject the entire batch to preserve once-and-once-only delivery semantics. That is, all messages within the batch that have been transferred to storage on the receiving node are backed out. The consequence of this is that all messages which need to be transferred to this next node (whether or not it is their final destination) are delayed, including the messages which could have been successfully stored on this next node. Such message transfer delays can be a significant problem if the reason for the delay persists.

Furthermore, it may be a requirement of the system that messages with the same ultimate destination are never sent out of order. In such cases, use of a dead-letter queue is unacceptable unless there is provided means to correct the ordering before the messages are finally delivered.

SUMMARY OF INVENTION

According to a first aspect of the present invention there is provided a method of message transfer between nodes of a communication network wherein messages transferred within a batch from a sender node to a receiver node are either all stored at the receiver node or the whole batch transfer is rejected with none of the messages of the batch being stored at the receiver node, the method including:

- responsive to rejection of a batch transfer due to a failure to store one or more messages of the batch at the receiver node, identifying which message or messages within the batch caused the rejection; and
- retrying transfer of a batch of messages with said identified messages excluded from the retried batch.

The invention enables batch transfer to be retried after a transfer failure, with an expectation that rejection-causing conditions associated with a particular identified message or messages will not result in recurring failure of the batch. Use of the invention can thus permit a batch transfer to proceed

after an initial failure, even if the failure was caused by a persistent problem.

The invention also reduces reliance on the availability of dead letter queues at receiver nodes, and by facilitating reduced use of dead letter queues makes it easier to maintain message ordering.

The invention has the additional advantage that, if message traffic is overloading one node such that message storage facilities (e.g. one or more message queues) are becoming full and some messages sent to the node cannot be successfully stored there, the messages which cannot be stored are retained on adjacent sender nodes rather than on the node which is having the problem, thus providing a pacing effect. The messages which fail (or certain selected messages which fail—see below) are backed out onto the sender node for retry rather than responding to an initial failure by placing all messages which fail into a dead letter queue at the receiver node.

Preferably, methods according to the invention include the step of transferring the identified problematic messages into a particular storage facility at the sender node (such as a defined retry message queue having an associated process for transferring problem messages to that queue) such that they are separated from the rest of the batch but are not discarded. Transfer of the batch (excluding the problem messages) can be retried after the separation, with or without further examination of the messages which are not excluded, with increased likelihood of success following the separation. The identified rejection-causing messages can subsequently be retrieved from the problem-message storage facility for retransmission, without impacting the success of transfer of the batch. Since some of the conditions which mean that messages cannot be successfully stored at the receiver node may be transient, the messages which were excluded from the resent batch are preferably retrieved from the problem-message storage facility periodically (e.g. after expiry of a timer or otherwise as determined by administration-defined parameters) to attempt retransfer.

Some provision for continued processing of problem messages is important where reliable once-only transmission of each message is a system requirement. Alternatively, for certain systems or certain types of message (e.g. a status query) it may be sufficient to communicate to the original sender of a message the information that a particular transfer of the message between two nodes has failed without retrying. Merely discarding the identified messages will be unacceptable to many applications, such as a funds transfer application within a banking system for example.

Methods according to the invention preferably include the steps of identifying and recording the destinations of said identified problem messages, and the retransmitting step involves retransmitting the batch excluding the identified problematic messages and excluding any other messages having the same (recorded) destinations. This aspect of the invention relates to methods of message transfer in which messages transferred within a single batch from a sender node to a receiver node can have different ultimate destinations. Thus, if the rejection of the batch was caused by problems associated with the destination of a particular message, other messages which would be rejected for the same reason are identified and excluded from the retransmitted batch. This exclusion of messages with identified problematic destinations will increase the likelihood of the resend being successful and so will, in many cases, avoid further back outs. This is particularly useful where the condition which caused the transfer failure is that a destination message queue at the receiver node is full or is otherwise unable to accept the addition of messages, since these are conditions which can be expected to result in transfer failure for any message sent to that queue. "Destination" in this context is preferably the final destination of the message, but alternative embodiments of the invention may distinguish between messages having different next-step destinations as will be explained below.

A first preferred embodiment of the invention includes the step of the receiver node communicating to the sender node an identification of each of the messages within the batch which could not be successfully stored at the receiver. In a second alternative embodiment of the invention, the receiver node reports back to the sender only those transfer errors which it identifies as being transient. According to this second embodiment, transfer errors which are permanent (e.g. specified destination address is invalid) can be dealt with by the messages in question being transferred to a dead-letter queue at the receiver since there is nothing to be gained by retrying transfer of these messages.

The exclusion of all messages having the same destinations as messages for which problems have been identified is preferably implemented as follows. On backout of a batch by a receiver node, all messages within the batch are also backed out at the sender node, and the messages which could not be stored are identified to the sender node. The sender node records the destinations of identified problem messages in a "message black list" of destinations. The identified messages are then removed from the first storage facility and transferred to a special storage facility defined for problem messages. The sender node now takes the remaining messages one by one from the first storage facility to include in a new batch for transfer to the receiver node, and at the same time compares the destination of each message with the destinations in the message black list. Any messages having these destinations are transferred to the special storage facility at the sender node instead of being included in the batch which is transmitted to the receiver node.

In accordance with a preferred embodiment which implements such exclusion there is provided a method of batched message transfer between nodes of a communication network wherein messages transferred within a batch from a sender node to a receiver node can have different ultimate destinations, and wherein either all messages within the batch are stored at the receiver node or the whole batch transfer is rejected and retained in storage at the sender node without being stored at the receiver node, the method including:

(a) recording at the sender node the destinations of all messages to be transferred within a batch;
(b) initiating transfer of the batch to the receiver node;
(c) responsive to rejection of a batch following failure to store one or more of the messages of the batch at the receiver node, identifying at the receiver node which message or messages within the batch caused the rejection;
(d) backing out the message transfer operation at the receiver node and communicating to the sender node an identification of said rejection-causing messages;
(e) backing out the message transfer operation at the sender node;
(f) recording at the sender node the destinations of said identified messages;
(g) transferring said identified messages and other messages having said recorded destinations into a problem-message storage facility at the sender node;
(h) retransmitting the batch of messages excluding said messages transferred to the problem-message storage facility; and

(i) retransmitting to the receiver node said messages from the problem-message storage facility separately from retransmission of said batch.

Steps (c) to (h) can then be repeated until the batch is successfully stored at the receiver node, and step (i) can be repeated until either all messages from the problem-message storage facility are successfully stored at the receiver node or a maximum retry count has been reached. Such repeats may not be performed consecutively, as it may be desirable to intersperse retries from the problem-message storage facility with a number of other batch transfers.

Methods of batch transfer according to the invention preferably involve an attempt being made to store at the receiver node each of the messages within the batch, such that a decision of whether it is necessary to back out the batch is only taken at the end of the batch transmission. If the decision is made at the end of the batch to backout, then the receiver node will notify the sender node which messages it was unable to deal with. An alternative which is also within the scope of the present invention is to backout the batch as soon as a failure to store one of the messages within the batch occurs (i.e. to detect and respond to failures as soon as they are identifiable, without having attempted to store all messages within the batch and so without necessarily having identified all problematic messages).

In cases where the retransmitted (modified) batch includes messages which still cause rejection, the steps of identifying messages which cause rejection of the batch transfer, recording their destinations, and retransmitting the modified batch which excludes messages having those destinations are preferably repeated until a batch of messages is successfully stored at the receiver. Repeated rejections may occur if the method rolls back the batch as soon as the first problem of message storage at the receiver node is identified and before an attempt is made to store all messages of the batch. It may also occur if a new transient problem occurs (e.g. if a queue on the receiver node in which a message must be put is now full), or if the retransmitted batch includes a new message or messages which were not part of the batch as initially sent.

The latter example may occur in systems in which resending of a modified batch entails transmitting all messages (up to a maximum size or number) held within a particular storage facility which are not identified for exclusion from that batch, including messages placed in storage since the initial unsuccessful transfer attempt. Thus, the sender system distinguishes between apparently problem-free destinations and destinations with identified problems and then controls the selection of messages for the next batch so as to exclude messages having the problem destinations but to include any messages having the apparently problem-free destinations regardless of whether they were part of the original batch or not.

This preferred feature of the invention may be implemented so as to exclude from the new batch any messages which have destinations other than those already recorded as being destinations of messages within the original batch. This would enable the new batch to include some messages which were not within the original batch, but only if the initial batch transfer attempt has already confirmed that there are no problems associated with the particular destinations of those new messages. An alternative which is also within the scope of the invention is to set up the system to restrict the modified batch to include only messages which were part of the original batch. Either of these two alternatives will increase the likelihood that transmission of a new batch following an initial failure will be successful.

In a preferred embodiment of the invention, storing of all of the messages of a batch at the receiver node comprises a message receiver process at the receiver node storing messages of the received batch in message queues at the receiver node for subsequent retrieval either for processing or onward transmission. The batch transfer is rejected only if not all of the messages within the batch can be stored in the message queues of the receiver node. In such a message queuing system, the destination message queues at the receiver node can include local message queues which are serviced by locally stored application programs and "transmission queues" for messages which are to be transmitted to another node for processing by a remote application. Such a system is described in more detail below in relation to a preferred embodiment of the invention.

According to a second aspect of the invention there is provided a message communication system having message storage means and having computer program means for supporting message transfer to and from nodes of a communications network of which said system is a first node. The system supports batched transfer of messages wherein messages sent within a batch from the first node to a receiver node may have different ultimate destinations, and wherein either all messages within the batch are stored at the receiver node or the batch transfer operation is rejected and backed out without any messages of the batch being stored at the receiver node. The system includes means, responsive to a communication from the receiver node indicating that a batch transfer is rejected and identifying which messages within the batch caused the rejection, for excluding said identified messages from a batch of messages to be transferred.

The system also includes means for identifying which message or messages within a batch of messages received by that system could not be stored at that system and so caused rejection of the batch transfer.

A system according to the invention preferably includes means for recording the destinations of the identified problematic messages and the means for excluding is adapted to ensure exclusion of all messages having these recorded destinations from the batch which is retransmitted after a rejection.

According to a third aspect of the invention, there is provided a communications network including a plurality of network nodes and communications links, each of said network nodes having associated therewith:

data storage means; and

program means for supporting batched message transfer between nodes of the communication network wherein messages transferred from a sender node to a receiver node can have different ultimate destinations, and wherein either all messages within a batch are stored at the receiver node or the whole batch transfer is rejected without any messages of the batch being stored at the receiver node. The computer program means includes:

means for identifying which message or messages within a batch received at that node has resulted in a rejection of a batch; and

means responsive to identification of the message or messages which caused rejection of a batch sent from that node for excluding said identified messages from a batch of messages prior to retrying transfer of the batch.

According to a fourth aspect of the invention, there is provided a computer program recorded on a recording medium, for supporting batch message transfer between nodes of a communication network. The program includes means for identifying which messages within a received batch are responsible for a batch transfer being rejected and for communicating that information to a sender node, and

means for controlling retransmission of a batch which was sent from that node and rejected so that the retransmitted batch excludes messages identified as having caused the rejection.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be described in more detail with reference to the accompanying drawings in which:

FIG. 1 is a schematic representation of the hierarchy of components of a data processing system in which the invention may be implemented;

FIG. 2 is a schematic representation of the transfer of a message from a first application to a second application on a different data processing system, using messaging and queuing;

FIG. 3 is a schematic representation of the two adjacent computer systems of FIG. 2 and of the interrelationships between the system entities involved in message communication;

FIG. 4 is an overview flow diagram showing the sequence of steps of message communication between application programs, including successful batch transfer;

FIG. 5 is a representation of the message flows between processes during normal forward processing of a method of communication between application programs; and

FIGS. 6A and 6B are a flow diagram showing the sequence of steps during batch message transfer according to an embodiment of the invention, in the case where transfer of the batch is rejected on the first attempt.

DETAILED DESCRIPTION

A preferred embodiment of the invention includes a method and apparatus for message transfer between network nodes, wherein messages are transferred in batches and, if the batch transfer fails, the messages within the batch which caused the failure are identified and then the batch is resent without those problem messages. In the following description of a preferred embodiment, the word "node" refers to the communications management programs which are the network entities to which messages are sent.

The present invention may be implemented within many different data processing systems and communications systems which are able to use batch transfer methods. The invention may be implemented in a computer program product which is adapted for use with any computer. For example, suitable data processing systems in which the invention may be used are IBM's RISC System/6000 computers, which run IBM's AIX operating system, and IBM's PS/2 personal computers, which run IBM's OS/2 operating systems. According to the preferred embodiment, the invention is implemented in a message-oriented middleware (computer program) product such as a product within IBM's MQSeries family of commercial messaging software products. The products within the MQSeries product family are each adapted to run on a specific one of a large number of different hardware and operating system platforms. Any one of these MQSeries products may implement the invention.

(IBM, MQSeries, RISC System/6000, PS/2, OS/2 and AIX are trademarks of International Business Machines Corporation.)

FIG. 1 is a simplified schematic representation of the hierarchy of data processing system resources of a system in which the invention may be implemented, demonstrating the hierarchical position of the message oriented middleware on top of the operating system (using the operating system resources) and underlying the application programs. The Figure shows a system **10**, comprising hardware **100** having network communication links **110** thereto and having operating system software **120** installed thereon, such as may be provided in any general computer. The system in which the invention is implemented also has communication-supporting (messaging) software **130** interfacing with the system's operating system. The messaging software provides support for a number of application programs **140**, which are the business applications run by a system user (e.g. an airline passenger booking facility run by a travel agency).

It will be helpful to set out some basic concepts of messaging and queuing. Messaging and queuing is a method of inter-program communication which allows programs to send and receive application-specific data without having a direct connection established between them. A message consists of two parts—application data and a message descriptor containing control information. The application data in a message is defined and supplied by the application program which sends the message. There are no constraints on the nature of the data in a message (for example, it could consist of one or more bit strings, character strings, binary integers, etc). Applications view the string of bits and bytes that make up a message as consisting of a sequence of items which each have a particular meaning and data type. In addition to the application data, a message has associated with it some ancillary data. This is information that specifies the properties of the message, and is used by the message queuing service to decide how the message should be processed. Some of this information must be specified by the sending application.

A message queue is a named object in which messages accumulate and from which they are later removed. Each queue belongs to one particular queue manager (which is the system service that provides the message-queuing facilities used by applications), and the queue manager is responsible for the maintenance of that queue. A message queue is not merely a stack: when messages are added to a queue, they are added at the end, and when messages are taken from a queue they are normally removed from the front (although facilities do exist for reading messages in other than FIFO order). The physical representation of a message queue depends on the environment, but can be a buffer or buffers in main storage, a file or files on disk or other permanent storage device, or both of these. The physical management of message queues is entirely the responsibility of a queue manager, and such details are not made apparent to application programs. Applications can view a message queue simply as a "black box" in which messages accumulate. Applications have access to message queues by using message queuing API calls—obtaining message queueing services by using the message queueing calls to communicate with the queue manager that is installed on the same system as the application (i.e. the local queue manager).

Applications communicate by agreeing to use particular named message queues, sending messages to the specific target queues that the application programs have agreed to read from. The locations of these queues need not be apparent to the applications which send the messages; each application interacts only with its local queue manager, and it is the network of interconnected queue managers that is responsible for moving the messages to the intended queues. In this way, the message queuing software greatly simplifies the level of complexity that is required of the application programs, removing the need for them to implement their own complex communications controls.

Message queuing communication between programs, using batch transfer of messages between adjacent network nodes, is provided by the MQSeries family of software products. The MQSeries products and the communications methods implemented in those products are described in the following publications:

"An Introduction to Messaging and Queuing" (IBM document number GC33-0805-00);

"MQSeries—Message Queue Interface Technical Reference" (IBM document number SC33-0850-01); and

"Messaging and Queuing Using the MQI", B. Blakeley, H. Harris & R. Lewis, McGraw-Hill, 1995.

Using the communications support of IBM's MQSeries products, communication between application programs is via message queues, as will be described with reference to FIGS. 2 and 3. A sender application **140** sends data via a message which it places onto a queue in storage, for a receiver application **140'** to sequently retrieve when it is ready. Every queue in an MQSeries system belongs to a queue manager (which is the executable program in an MQSeries product), and the queue manager provides access to the queues in response to requests from application programs (or from administration tools). There is no requirement for a logical connection between the application programs themselves and the use of queues controlled by queue managers facilitates asynchronous communication, so each application program can run independently. The queue manager software provides for reliable storage of queued messages, not deleting a message from a sender system until it has been safely stored at the receiver system.

Application programs can put messages onto local queues which are managed by a local queue manager program **130** (and which queues are held in the main memory or disk storage of the local system) and retrieve messages from them. A remote queue **130'** is one which belongs to a queue manager other than the one to which the application **140** directly connects. Access to a remote queue involves communication between the local queue manager **130** and the remote queue manager **130'**. Applications can place messages on remote queues but cannot read messages from them.

The mechanism by which queue managers arrange to forward messages to remote queue managers are transmission queues **160**. When a queue manager receives a request to put a message on a remote queue **170'**, it actually puts it on a particular transmission queue **160** which is associated with the queue manager **130'** which is the target for the request. A transmission queue forms one end of the link between a pair of queue managers. All messages whose immediate destination (i.e. the next step of their transfer across a network) is the same queue manager can be placed in the same transmission queue, regardless of their final destination. Thus, only one transmission queue is generally needed for moving messages in one direction from one queue manager to another, although there can be more than one. Transmission queues containing messages to be sent to queues belonging to remote queue managers enable the movement of messages to remote queues to be carried out in stages between adjacent queue managers. The staging of message transfer is invisible to the application programs involved in the communication.

Referring now to FIG. 3, queue managers **130,130'** may store messages onto a number of different queues. If the messages are eventually to be processed by local application programs then the queue manager stores them on local destination queues **170**; and if the messages are eventually to be processed by a remote application, then the queue manager stores them in the special local queues known as transmission queues **160**. There may be a plurality of local destination queues and of transmission queues controlled by a particular queue manager, as will be explained below. The messages on a transmission queue are extended by the queue manager to include a transmission queue header in addition to the application message (the data being transferred by an application). The transmission queue header is an architected descriptor containing the name of the destination queue and the message descriptor. Messages on destination queues include the application data and a message header specifying control information.

The transport relationship between two queue managers is known as a channel. The key elements defining a channel are the name of a transmission queue, information concerning the transport processes or programs **180,190'** which send or receive messages over the channel (these processes, which are part of the queue managers, are known as message channel agents—hereafter MCAs), and communications protocol and target system information for the destination to which messages on the transmission queue are to be sent. The association between a particular channel definition and the various data model entities involved in the message communication is represented by broken lines in FIG. **3**. Each named channel is defined in both the sending and receiving nodes. The channel name is used in the transmissions between the sender and receiver processes to identify the channel to the receiver or for a receiver to request that messages from a particular channel be sent. Channel definition has some information which is common for all environments and some which depends on the operating system environment and underlying communications protocol to be used.

The communication of messages between queue managers is carried out by MCAs working in pairs across specific channels: one sender **180** and one receiver **190'**. A pair of MCA processes uses a transport connection **195** such as a VTAM APPC session or a TCP/IP connection as a transport layer. Message traffic in the opposite direction flows between a sender **180'** and a receiver **190** on a different channel, the channels being used effectively as unidirectional pipes between nodes. There are four types of MCAs:

Sender—which takes messages from a transmission queue and sends them to a Receiver or Requester;

Receiver—which receives messages and queues them;

Requester—which sends a single message to cause a Sender or Server to be started remotely;

Server—which is started by a message from a requester, and then becomes a Sender.

An MCA **180** dequeues messages from transmission queues and transmits them over the transport connection **195**. The receiving MCA **190'** queues the messages to the destination queues **170** named in the message header. These two units of work, dequeue and enqueue, are performed such that any failure at any point in the protocol can be detected and rectified (as described below) so that each message is delivered once and once only. In the case where the destination queue is more than one hop from the original transmission queue, the receiving MCA will queue the message on another transmission queue for the next hop. This provides a safe store and, in the event that the next connection is unavailable, the necessary asynchronism to allow this first stage of transmission to still be carried out. The message format and the safe movement protocol are transport layer independent so that MCAs can support different transport protocols on different channels. The protocols used by the MCAs are described below.

A channel may be started in a number of different ways:

1. a terminal operator may issue a START CHANNEL command;
2. the channel can be triggered, a Sender MCA being started automatically by a queue manager when a message arrives on the transmission queue; or
3. by a network request—the communications transport being configured to automatically start an MCA when a request from the network is received. Receiver, Server and Sender channels could be configured this way.

Before any messages or data can flow down a channel, the two MCAs which are to use it must first negotiate the way in which they are going to communicate. Thus, channel initialization involves negotiation of certain protocol parameters, such as which communication partner is going to do any needed conversion of control and message header data. Two MCAs may be running on systems using two different data formats. For example, one may be using ASCII and the other EBCDIC. One may be encoding numbers left to right, the other right to left. The control information and message header data must be converted from the sender's representation to the receiver's. Data conversion over channels applies only to control information (such as destination queue name, control field lengths, and the like): no application data conversion is performed by MCAs, since MCAs do not need to interact with the application data in a message when they transmit it.

The method of delivering messages between applications on different computer systems involves the following steps, described with reference to FIGS. **4** and **5**:

An application sends a message to a target destination queue for processing by another application by issuing (**200**) an MQPUT command. The local queue manager reads the destination queue name specified by the application in the message's header and determines (**210**) where to put the message. If the destination queue is a local queue then the local queue manager puts (**220**) the message into that local queue. The unit of work including the operation of putting the message to a queue must be committed before the message is available to other applications. An application serving that local queue can then asynchronously issue MQGET (**230**) to take the message from the queue for processing. The MQPUT and MQGET operations are within two separate units of work.

If the destination queue is not the responsibility of the local queue manager, then the local queue manager puts the message onto a local transmission queue (**240**), for transfer to another queue manager. There may be a plurality of transmission queues defined for each queue manager, but a one-to-one correspondence between transmission queues and remote destination queues is not necessary. All messages that are to be passed between two adjacent queue managers (that is, all messages to be sent from a first queue manager which have a common nearest neighbor queue manager in the direction of their respective target destination queue managers) can be put in the same transmission queue. It is equally possible to have a number of transmission queues for traffic going to the same next node. A maximum batch size is specified (for example 50 messages) to limit the number of messages which will have to be resent in the event of a failure during transmission of a batch of messages. The unit of work **300** which puts the message to the transmission queue must be committed before the message is available to other processes.

The local queue manager (or an end user) starts a sender MCA to transmit messages to the next queue manager. The sender MCA then gets messages (**250**) (issues MQGET)

from a transmission queue owned by this queue manager and transmits them as a batch to the next queue manager on the way to the destination queue manager or queue managers. Each message is either transmitted in one transmission or as a plurality of transmission segments in a plurality of transmissions if the messages are too large for the transport connection to send in one package (e.g. a message might be 4 Megabytes in size and the maximum transfer size 32 kilobytes). The steps of getting and transmitting messages is performed within a syncpoint-manager-controlled unit of work **330**, which is held in-doubt by the sender at this stage. Log records are written specifying the in-doubt state of the resource updates. The batch has a request for confirmation of receipt of the batch attached to it: this is implemented by the last message (or the last transmission segment of the last message) of the batch having a Request_Confirm control flag set in its transmission segment header.

Each message has a message sequence number associated with it—one of a monotonically increasing sequence of numbers, uniquely assigned to a single application message on a channel. Message sequence numbers are used to resynchronize between sender and receiver in the event of a link failure or program failure. The highest message sequence number in the batch is taken as the logical unit of work identifier (LUWID)—a unique value defining a batch of messages on a channel which are under control of a syncpoint manager.

The receiver MCA receives (**260**) the messages and the receiver queue manager determines (**210**) where each message is to be sent (as the sending queue manager program did previously). The receiver queue manager puts the messages (using MQPUT) within a syncpoint-manager-controlled unit of work **360** to queues belonging to the receiving computer system's queue manager, which may be the actual application-specified destination queue for a particular message or may be a related transmission queue for the next hop towards the target system.

Either all of the messages in the batch of messages transferred by MCAs are successfully received and queued by the receiving queue manager or the batch is rejected as a whole and not safe stored at the receiver (the unit of work is rolled back). If the batch is successfully received and queued then the receiver sends an acknowledgement of receipt and storage (a Status segment indicating "No error" is transmitted), having logged the LUWID and committed the batch of messages together as an atomic action. On receipt of the positive acknowledgement the sender also commits the batch of messages using the LUWID, this commit of the MQGET operation deleting the messages from the transmission queue. The next batch can then be started. If no messages are left on the transmission queue (and a preset time interval has expired) or a request to close the channel has been received, then the connection can be terminated.

To complete the assured delivery of messages following successful queuing by the receiving queue manager, the target application which services the destination queue can issue MQGET to get messages from the queue as part of a unit of work **390** under the control of its local syncpoint manager, to allow rollback of the message to the queue in case of application failure or commit of a successfully processed message to delete it.

As noted previously, there are various reasons why it may not be possible to successfully store one or more of the messages of a batch at the receiving node. A communication link or program failure will require rollback of any in-doubt (uncommitted) batch of messages, but for such failures the

requirement to return system resources to a consistent state does not necessitate distinguishing between particular messages within the batch (although the system may be set up to ignore certain "non-persistent" messages after such a failure). Other conditions may prevent the successful storage of only certain messages within a batch. Examples in a message queueing environment are that the named target queue for a particular message does not exist or it is already full.

If the batch is rejected, an acknowledgement of rejection (a Status segment indicating Error—which may include details of the error) is transmitted to the sender which then rolls back its in-doubt messages onto the transmission queue ready for retry, and terminates the channel. If a batch of messages is rolled back, the sequence number or LUWID must also be rolled back, to the value of the last successfully committed batch. If no confirmation is received, due to transport or communication-partner failure, then the channel is terminated by the sender and the receiver MCA's unit of work is rolled back. If the sender has not yet sent a confirm request then the sender MCA should also roll back. If it has sent a confirm request then its log records and those of the receiver program must be examined to determine whether it should be committed or rolled back. The MCAs automatically perform the determination of whether the first unit of work should be committed or rolled back (unless contact cannot be reestablished in which case the operator may take the decision).

At the end of each batch, if the receiving node has been unable to store any one of the messages within the batch, then the receiver node rejects and backs out the batch as described above. Simply backing out the batch onto the sender node's transmission queue and attempting retry of the batch transfer may result in repeated failure of the batch transfer for the same reason (e.g. if the rejection was caused by a permanent problem such as an invalid message address and possibly also if caused by transient conditions which still exist at the time of the retry). Such transfer problems may be associated with only some of the messages of the batch. To reduce the recurrence of failures associated with specific messages, the following operations are performed (see FIG. **6**).

The sender node maintains **400** a record of the final destination addresses (target queue manager and queue name) of each of the messages which it sent within the batch—this information being obtained from the message headers. On failure to store one or more of the messages of the batch at the receiver node, the receiver node queue manager notifies **430** the sender node queue manager which messages it was unable to successfully store by specifying the ordinal numbers of these messages within the batch and backs out the batch. (Of course, any unambiguous message identification may be used as an alternative to ordinal numbers). The sender node uses the information returned to it by the receiver node and its record of message destinations to identify the destinations of all messages which could not be stored. These destinations of rejection-causing messages are recorded **460** in a list at the sender node (referred to as the "destination black list" hereafter).

The sender node also backs out **450** the batch transfer, causing all of the messages in the batch to be reinstated in the transmission queue at the sender node. The sender node then selects the identified numbered messages (those which the receiver identified as causing problems) and removes them **470** from the transmission queue—transferring them to a predetermined retry queue. In order to preserve once-and-once only semantics, this transfer is performed with syncpoint coordination and is atomic.

The sender node then takes **480** the messages remaining on the transmission queue one at a time for retransmission to the receiver node in a new batch, referring to the destination black list to identify **490** any messages having the same destinations as those which caused problems on the first attempt. Any messages that are identified as having destinations that are on the black list are transferred **490** to the retry queue and are not included in the batch which is then retransmitted **500**. The retried batch consists only of messages that have destinations that are not on the sending node's back list.

In general, the receiver will now be able to store **510** all messages of the batch and the message transfer is committed **520,530**.

If there remain problems associated with some of the messages within the batch, then the process of backing out the batch transfer and separating these messages and other messages having the same destinations prior to resend is repeated. However, the avoidance of sending messages with problematic destinations increases the probability that all of the remaining messages in a batch can be successfully stored, and the expectation for many systems in which the invention is implementable is that the retransmitted batch will be transferred successfully.

Some of the conditions which mean that messages cannot be stored successfully at the receiving node may be transient. For example, the queue on which a message should be stored might be full, but then an application program processes some of the messages on the queue and it ceases to be full. Secondly, there may be a temporary shortage of available disk space. Thirdly, the queue may be "PUT inhibited"—an administrator or other person or application having set the queue to avoid further messages being added to it. Periodically, as determined by administration-defined parameters, instead of sending a batch of messages from the sender node's transmission queue, the sender node sends **540** a batch taken from its retry queue. The administration-defined parameters preferably comprise a preset time period following the addition of a message to the retry queue, but can equally be a preset number of batches which should be taken from the transmission queue before a batch is taken from the retry queue, or any other suitable parameter. The process of taking messages from the retry queue for retransmission controls this batch to include no more than one message having each destination. The receiver communicates **560** to the sender a confirmation of whether messages within the batch of messages from the retry queue were successfully stored **550** at the receiver node. Since there is a likelihood that only some of the retried messages will be successfully transferred from the retry queue, the process controlling retransmission from the retry queue responds to a confirmation of successful storage of any message by attempting to resend **580** all messages in its retry queue which have the same destination.

Once the sending node has successfully sent all of the messages on its retry queue which have the same destination, that destination is erased **620** from the destination black list.

The present invention is preferably implemented so as to identify and isolate **470,490** from a batch of messages any messages which could not be successfully stored in a named destination queue or transmission queue at a receiver node. In this context, storing of messages in a dead-letter queue does not constitute "successful" storage at the receiver node as the message has not reached the intended target queue and so invokes a backout. This does not mean that storage in a dead-letter queue of the receiver node is unacceptable but

only that, in the preferred embodiment of the invention, messages invoke a backout and the steps of identification and exclusion of messages are performed when a message cannot be stored in the correct target queue. Messages are then only placed in a dead-letter queue after repeated failures to transfer them "successfully". It was noted above that "dead letter queues" may not be defined for all systems and even if defined will not always be available and so minimizing reliance on dead-letter queues is desirable. Furthermore, a system using dead letter queues requires additional message ordering correction facilities to be provided. Clearly, where the difficulty in storing messages at a receiver node is due to a general resource shortage, the dead-letter queue may be compromised to the same extent as other resources. A solution to these problems according to the embodiment of the invention is described in more detail below.

Following a rollback resulting from communication link or program failure, the sending MCA will try to re-establish a channel and resynchronize with the receiving MCA in order to resend the failed batch. Channel resynchronization is achieved during channel initialization. The sender MCA retrieves from its log the in-doubt LUWID, or message sequence number of the last message sent for which a confirmation was also sent. The receiving MCA will check his logged LUWIDs or sequence numbers to determine whether he is in sync with the sender. As a result of the comparison, he will confirm or reject the resynchronization request by returning an appropriate Status segment, containing the LUWID or sequence number of the last successfully committed message or batch of messages at his end. If this value matches the sender's, the sender may commit the previously sent messages, and commence sending the next one. If the receiver's value matches the previous LUWID or sequence number, the sender rolls back and resends the previous message or batch.

The MCAs thus use a syncpoint manager to control each batch as a logical unit of work. The unit of work including the MQGET of the sender message queue manager and the unit of work including the MQPUT of the receiver message queue manager are logically linked in that both are held in doubt until the receiver is ready to commit, messages being committed at the receiving end before deleting them at the sending end using a single-phase commit protocol. Two phase commit is not required as the sender acts as a commit coordinator. Any system failure that occurs before the end of the batch, either at the sender or receiver, may require the unit of work to be backed out during a resynchronization phase. This single-phase commit using logical linkage of units of work on different systems avoids the problem of a two-phase commit needing to synchronize (lock) all participating resources in a distributed unit of work. According to this commit processing, resource managers do not actually have to synchronize with each other. A limited period of inconsistency between resources as viewed by applications is accepted, but final consistency is assured since atomic transaction processing is assured.

The destination black list is held as an in-memory table (i.e. in volatile storage). On restart after a system or program failure, it is rebuilt by browsing the retry queue and recording message destinations from the message headers. An alternative to this is to actually retrieve each message from the retry queue and to attempt to resend simultaneously with rebuilding the retry queue.

Some messages may never succeed in being stored successfully at the receiving node, for example if they were generated with an invalid destination address. To avoid such messages remaining in the retry queue indefinitely, a maximum retry count is used at the sender node after which the message is deemed undeliverable. Such an undeliverable message is then transferred to a dead letter queue (which in this case may be located either at the sender node or the receiver node—although to implement the latter requires the receiver node to be given confirmation of when to do this rather than reject the batch).

The embodiment of the invention described in detail involves the receiver node reporting back to the sender all transfer errors and identifying the messages involved. An alternative which is within the scope of the present invention is for the receiving node to report only those transfer errors which it considers to be "transient" to the sending node, and to transfer errors which it considers to be "permanent" (for example, an invalid destination address) to the receiver node's dead letter queue. What conditions are to be identified as "transient" and "permanent" can be defined by a system administrator. A simple implementation defines the following three easily recognizable conditions as transient: a queue to which one of the messages of the batch should be put is full; or a queue is PUT-inhibited; or disk storage is full. All other conditions are defined as "permanent" and do not cause a problem-message identification to be communicated to the sender node.

In such an embodiment of the invention, the method steps of identifying problematic messages within a batch and placing them in a retry queue for retransmission separately from the batch are preferably performed before any attempt is made to place messages in a dead letter queue. A dead letter queue (which may be located at either the sender node or the receiver node) is then only used for messages determined to be undeliverable after use of the retry queue. This reduction of reliance on dead letter queues is particularly useful when message ordering is important (as it is in many systems), as it is difficult to re-order messages in correct sequence when a dead letter queue is used. It is generally desirable to optimize the message transfer method for the situations where there are no message transfer errors or very few, in view of the very low incidence of such errors.

The embodiments of the invention described above in detail include the steps of separating identified rejection-causing messages from the batch of messages on the sender node's transmission queue, by placing those identified messages and other messages having the same addresses into a special retry queue. An alternative embodiment of the invention does not transfer messages in this way but maintains the identified messages on the transmission queue. According to such an embodiment, the transmission queue is browsed with reference to the message black list and messages having identified problematic destinations are bypassed (i.e. left on the transmission queue) when retrieving messages for retry of the batch transfer.

The embodiments of the invention described above use identification of final message destinations to exclude from a resent batch messages which are identified as causing problems and messages which have the same ultimate destinations. Such embodiments are most easily implemented in "adaptive message routing" systems in which a sender node has information concerning the final destination of a message and determines, from this information and network configuration information, the next adjacent node to which the message should be sent. It is also known in messaging systems to employ "source routing", in which a first sender node determines a complete route for message communication between network nodes and identifies each of the network nodes which are to be part of that route. In

such source routing systems, for example, it is possible to distinguish between messages by reference to the next adjacent nodes to which they are to be sent. In such cases, an identification of message "destination" and a "destination black list" may refer to the next adjacent node, such that an implementation of the present invention excludes from a resent batch of messages all messages having the same next adjacent node along their predetermined communication route.

As an alternative to the embodiments of the invention described above, storing of problem messages in a "dead-letter queue" on the receiver node may be considered a successful storage such that there is no need to back out the batch as long as all messages within the batch are stored at the receiver. According to this embodiment of the invention, the method steps of identifying messages and their destinations and excluding messages from a new batch are only performed when messages which cannot be stored to the named target queues also cannot be stored in a dead-letter queue.

As mentioned above, the destination black list of each sender system can be held in an in-memory table. Alternatively, the black lists can be stored in non-volatile storage (e.g. disk storage) so that it need not be recreated at restart of the system. In this case, if message ordering is a system requirement, the black list must be stored in non-volatile storage within the same unit of work as is used to transfer messages between the transmission queue and the retry queue.

While the embodiments of the invention described in detail above use batching of messages both when transferring messages from the transmission queue of the sender to the receiver node and when transferring messages from the problem-message queue, embodiments of the invention may implement a reduced maximum batch size when trying messages from the retry queue and this may be a batch size of one (i.e. individual transmission) to ensure that messages for which the reason for initial failure is transient may proceed as soon as possible even if other messages on the problem-message queue repeatedly fail.

The embodiments described above implement the invention within a software product adapted for installation on a particular type of computer for use with the corresponding computer operating system. The invention could equally be implemented as a feature of the operating system itself, as many features of a messaging system may be implemented within an operating system if desired. Alternatively, the invention may be implemented higher up the hierarchy of data processing system resources—in an application program which provides messaging functions. The invention may also be implemented in communications controlling software or hardware of a packet switching communications network.

We claim:

1. A method of message transfer between nodes of a communication network wherein messages transferred within a batch of messages from a sender node to a receiver node can have different ultimate destinations, and wherein either all messages within the batch are stored at the receiver node or the whole batch transfer is rejected and retained in storage at the sender node without being stored at the receiver node, the method including:

responsive to rejection of a batch following failure to store one or more of the messages of the batch at the receiver node, identifying which message or messages within the batch caused the rejection; and

retrying transfer of a batch of messages with said identified messages excluded from the retried batch.

2. A method according to claim 1, including the step of recording at the sender node the destinations of the identified messages, said retried batch excluding said identified messages and other messages having said recorded destinations.

3. A method according to claim 2, including transferring said identified messages and other messages having said recorded destinations from a first message storage facility at the sender node to a problem-message storage facility at the sender node for subsequent retry of transfer of said excluded messages from the problem-message storage facility separately from said retry of the batch transfer from said first message storage facility.

4. A method according to claim 3, including the steps of incrementing a retry counter for each retry of message transfer from the problem-message storage facility, and repeating retry from the problem-message storage facility and incrementing of said retry counter until either all messages from the problem-message storage facility have been successfully stored at the receiver node or a preset maximum retry count is reached.

5. A method according to claim 1, wherein the sender node selects messages for inclusion in the batch which is to be retried without limiting only to messages which were included in the rejected batch.

6. A method according to claim 1, wherein said identification step includes the receiver node identifying which messages caused the rejection and communicating to the sender node an identification of said identified messages, the sender node then selecting said identified messages to exclude them from the retry batch.

7. A method according to claim 6, wherein said receiver node determines which of said identified messages cannot be stored at said receiver node due to predefined transient conditions and then communicates to the sender node an identification of those messages which cannot be stored due to said transient conditions.

8. A method according to claim 1, including:

maintaining at the sender node a record of the destinations of all messages to be transferred;

responsive to rejection of a batch message transfer following failure to store one or more of the messages of the batch at the receiver node, identifying at the receiver node which message or messages within the batch caused the rejection;

sending an identification to the sender of said rejection-causing messages;

identifying at the sender node messages having approved destinations which are the destinations of messages within said rejected batch other than the destinations of said identified rejection-causing messages;

selecting at the sender node for inclusion in a new batch only messages having said approved destinations.

9. A method according to claim 1, wherein the storing of all of the messages of a batch at the receiver node comprises a message receiver process at said receiver node storing all messages within the received batch to message queues at said receiver node for subsequent retrieval either for processing or onward transmission, the transfer of the batch being rejected if not all of the messages within the batch can be stored in said message queues at the receiver node.

10. A message communication system supporting message transfer to and from nodes of a communications network of which said system is a first node, wherein messages sent within a batch from said first node to a receiver node may have different ultimate destinations, and wherein either all messages within the batch are stored at

said receiver node or the batch transfer operation is rejected and backed out without any messages of the batch being stored at the receiver node, the message communication system including:

means, responsive to a communication from the receiver node indicating that a batch transfer is rejected and identifying which messages within the batch caused the rejection, for excluding said identified messages from a batch of messages to be transferred.

11. A system according to claim **10**, including means for maintaining a list of destinations of messages sent in a batch from said first node to another network node, means responsive to said communication identifying messages which caused rejection of the batch for identifying the destinations of rejection-causing messages, and means for excluding from a batch of messages to be transferred from said first node said identified messages and other messages having said identified destinations.

12. A system according to claim **10**, having means for sending messages in a batch from a first message storage facility of said system to message storage facilities at a receiver node, said system including means for transferring said identified messages to a problem-message storage facility at the first node from which said identified messages can be subsequently retrieved for transfer to the receiver node separately from batch transfer of messages from the first message storage facility.

13. A system according to claim **12**, including:

means for incrementing a retry counter when said identified messages are retrieved from said problem message storage facility for transfer to the receiver node; and

means for transferring messages from said problem-message storage facility to a dead-letter queue if a predefined maximum retry count is reached before all of said messages of said problem-message storage facility are successfully transferred and stored at said receiver node.

14. A system according to claim **10**, including means at said first node for receiving batches of messages from sender nodes of a communications network and for rejecting transfer of a batch on failure to store one or more messages of the batch at said first node, said system including means for communicating to a sender node an indication that a batch transfer is rejected and an identification of the message or messages which could not be stored.

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United States Patent [19]

Johnson et al.

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[45] **Date of Patent: Sep. 22, 1998**

[54] **COMPUTER BASED RECORDS MANAGEMENT SYSTEM METHOD**

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[21] Appl. No.: **508,370**

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[51] **Int. Cl.**[6] **G06F 17/30**

[52] **U.S. Cl.** **707/100**; 707/204; 707/104; 707/200; 707/205; 707/101; 707/103; 707/9; 711/170; 711/100; 364/570

[58] **Field of Search** 395/600; 364/570; 707/204, 104, 200, 205, 101, 103; 711/170, 100

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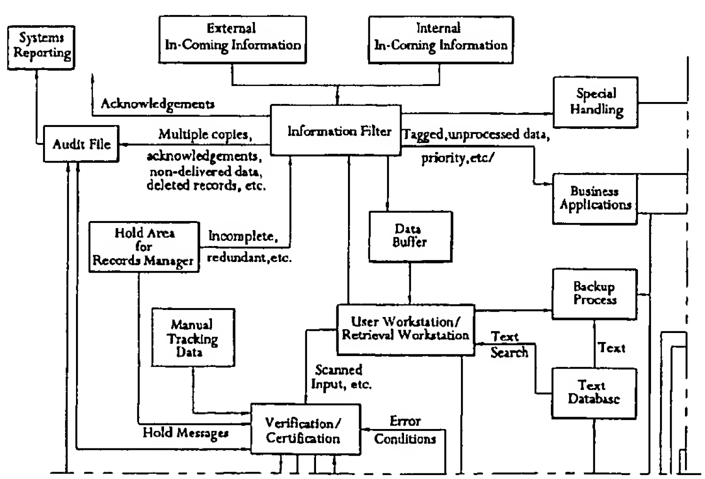
[57] **ABSTRACT**

A computer based records management system comprises an information filter for assuring that record data units offered to the system for storage are complete and not redundant. These record data units may be electronic in nature, scanned from paper, digitally formed from audio, video or otherwise formed as digital data information media, an objective of the disclosed system being to eliminate paper or microform record keeping. If record data units comprising documents are incomplete or redundant, the data units may be queued for special handling, returned or otherwise disposed of. Record data units accepted for system entry are acknowledged and preferably tagged to enable tracking and forwarded for unit verification and certification. Verification and certification includes examination of units for compliance with preset criteria. Once a unit is found to meet the criteria, the unit is stored in permanent storage along with a disposal schedule determined for that unit. Only users meeting predetermined security levels may alter or dispose of a stored unit prior to scheduled disposal. Moreover, reasons for such alteration or destruction are required from the cleared user, and an associated data field must be completed. Consequently, the present system provides for record data unit tracking and audit trails in the event of any requirement for regulatory or legal compliance with discovery or other record unit requests. The present invention also permits reconstruction of the record units of an enterprise in the event of a catastrophic event.

38 Claims, 10 Drawing Sheets



L Number	Hits	Search Text	DB	Time stamp
1	5891	(application near2 program) and queue	USPAT	2004/05/06 11:26
2	25	(business near2 application near2 program) and queue	USPAT	2004/05/06 11:27
4	24	((business near2 application near2 program) and queue) and @ad<20001101	USPAT	2004/05/06 11:27
-	4401	message near4 queue	USPAT	2004/05/05 13:56
-	577	(message near4 queue) and journal$4	USPAT	2004/05/05 13:53
-	3	(message near4 queue) and journal$4 near2 module	USPAT	2004/05/05 13:55
-	1	6351775.pn.	USPAT	2004/05/05 13:55
-	286	(message near4 queue) and ((first same second) near3 queue)	USPAT	2004/05/05 13:57
-	69	((message near4 queue) and ((first same second) near3 queue)) and balanc$3	USPAT	2004/05/05 14:44
-	1	(message with queue with management).ti.	USPAT	2004/05/05 14:44
-	4	(message with queue with management).ab.	USPAT	2004/05/05 14:47
-	665	queue with management with system	USPAT	2004/05/05 14:47
-	134	(queue with management with system) and 709/2$$.ccls.	USPAT	2004/05/05 14:47
-	125	((queue with management with system) and 709/2$$.ccls.) and @ad<20001101	USPAT	2004/05/05 15:04
-	63	(((queue with management with system) and 709/2$$.ccls.) and @ad<20001101) and track$3	USPAT	2004/05/05 15:00
-	11	(((queue with management with system) and 709/2$$.ccls.) and @ad<20001101) and track$3 near10 states	USPAT	2004/05/05 14:50
-	5	((((queue with management with system) and 709/2$$.ccls.) and @ad<20001101) and track$3) and ((prevent$3 avoid$3) with duplicat$3)	USPAT	2004/05/06 11:25
-	30	intelligent near3 queue	USPAT	2004/05/05 15:04
-	28	(intelligent near3 queue) and @ad<20001101	USPAT	2004/05/06 11:27